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RESEARCH MEMORANDUM

ROCKET-MODEL INVESTIGATION OF HINGE MOMENTS ON A TRAILING-EDGE CONTROL ON A 52.5° SWEPT WING BETWEEN MACH NUMBERS OF 0.70 AND 1.80

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS

WASHINGTON
August 12, 1957

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ROCKET-MODEL INVESTIGATION OF HINGE MOMENTS ON A TRAILING-EDGE CONTROL ON A 52.5° SWEPT WING BETWEEN MACH NUMBERS OF 0.70 AND 1.80

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SUMMARY

A free-flight investigation to determine the hinge-moment characteristics of a trailing-edge control on a swept and tapered wing has been conducted through the use of a rocket-powered model. The model consisted of a pointed cylindrical body equipped with a cruciform arrangement of 52.5° swept wings with an aspect ratio of 3 and a taper ratio of 0.2. The wing panels in one plane featured constant-chord, inboard, trailing-edge controls hinged at 40 percent control chord, one control being modified by a single row of perforations near the trailing edge. Test Mach numbers ranged from 0.7 to 1.8.

Control hinge moments were small throughout the speed range for all combinations of angle of attack and control deflection tested.

INTRODUCTION

The fairly recent ability of piloted aircraft to operate near and beyond the speed of sound has resulted in a greater need for the aerodynamic balance of control surfaces not only to decrease the power requirements of control booster systems but also to allow the pilot some control in the event of booster system failure. Although several means of increasing control aerodynamic balance are available, possibly the most obvious is to change the normally forward location of the control hinge line to a location nearer the control aerodynamic center. This method has been used successfully in previous investigations (see, for example, refs. 1 to 5) and was used also in the present test. Since control-aerodynamic-center location generally varies from about 35 percent control mean aerodynamic chord at subsonic speeds to about 50 percent control mean aerodynamic chord at supersonic speeds, a compromised value

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of 40 percent control mean aerodynamic chord was chosen as the hinge-line location in the present investigation. This investigation utilized a rocket-powered model with a 52.5° swept and tapered wing embodying partial-span, constant-chord, trailing-edge controls with 67 percent overhang balance. A single row of holes was drilled near the trailing edge of one of the two controls. It was reasoned that this would provide additional aerodynamic balance and by simultaneously testing two control configurations would allow more efficient use of the research vehicle.

Control hinge moments were measured at various combinations of angle of attack (ranging from $\pm 4^{\circ}$ to $\pm 10^{\circ}$ at subsonic speeds and $\pm 0.3^{\circ}$ to $\pm 3^{\circ}$ at supersonic speeds) and control deflection $\left(\text{up to } \pm 5\frac{1}{2}^{\circ}\right)$ at several Mach numbers between 0.7 and 1.8 for both controls. Reynolds number based on wing mean aerodynamic chord varied from 3 million to 13 million.

Results are presented herein and compared with linearized theory, where available.

SYMBOLS

c	wing chord, ft
c_f	control chord, ft
$\bar{c}$	wing mean aerodynamic chord, ft
S	total wing area in one plane, sq ft
M'	area moment of control surface rearward of and about hinge line, ft^3
δ	control-surface deflection at inboard end measured parallel to model center line (positive when trailing edge is down), deg
α	angle of attack at model center of gravity, deg
β	angle of sideslip at model center of gravity, $a_Y \Big/ \frac{\Delta a_n}{\Delta \alpha}$, deg
$\ddot{\theta}$	model angular acceleration in pitch, $radians/sec^2$
M	Mach number
R	Reynolds number based on $\bar{c}$

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q free-stream dynamic pressure, lb/sq ft

a_n model normal acceleration at center of gravity, g units

a_Y model transverse acceleration at center of gravity, g units

g acceleration of gravity, 32.2 ft/sec^2

H control hinge moment, ft-lb

I_Y model moment of inertia in pitch, slug-ft^2

M_Y pitching moment about model center of gravity, ft-lb

C_h control hinge-moment coefficient, $\frac{H}{2M'q}$

C_N model normal-force coefficient, $\frac{(\text{Model weight})(a_n)}{qS}$

C_m model pitching-moment coefficient, $\frac{M_Y}{qS\bar{c}}$

Δ increment

$\frac{\Delta C_h}{\Delta \alpha}$ incremental change in C_h divided by incremental change in α at constant δ, per deg

$\frac{\Delta C_h}{\Delta \delta}$ incremental change in C_h divided by incremental change in δ at constant α, per deg

$\frac{\Delta C_N}{\Delta \alpha}$ incremental change in C_N divided by incremental change in α at constant δ_a, per deg

$\frac{\Delta C_N}{\Delta \delta_a}$ incremental change in C_N divided by incremental change in δ_a at constant α, per deg

$\frac{\Delta C_m}{\Delta \alpha}$ incremental change in C_m divided by incremental change in α at constant δ_a, per deg

$\frac{\Delta a_n}{\Delta \alpha}$ incremental change in a_n divided by incremental change in α at constant δ_a, per deg

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Subscripts:

p	control with perforations near trailing edge
av	average of both controls
o	out of trim

MODEL AND TESTS

Model

The hinge-moment model used in this investigation consisted of a cylindrical body, with ogival nose and tail sections, equipped with a cruciform arrangement of swept tapered wings. A drawing of the model, showing overall dimensions, is presented in figure 1(a) and photographs of the model are shown in figure 2.

The solid magnesium-alloy wings had an NACA 65A006 airfoil section parallel to the free stream, a taper ratio of 0.2, an aspect ratio of 3, and a 52.5° angle of sweep at the quarter chord. The wing panels in the pitch plane embodied constant-chord (15 percent exposed wing root) trailing-edge controls which extended over the inboard 60 percent of the exposed wing span. The controls were hinged at 40 percent control chord and attached to the wing through two roller bearings. The controls were of modified double-wedge airfoil section and of solid-steel construction. The deflection angle at which the controls unported was greater than any control deflections experienced in flight. The control on the left wing was partially perforated with a single row of 1/8-inch holes along the 80-percent-control-chord line. Details of the wing and control are shown in figure 1(b). Physical constants of model are presented in table I.

Flight Test

The flight test was conducted at the Langley Pilotless Aircraft Research Station at Wallops Island, Va. The model was boosted to a Mach number of 1.8 and during the coasting period which followed data were telemetered to a ground receiving station and recorded.

Flight conditions resulted in the values of Reynolds number and dynamic pressure presented as a function of Mach number in figure 3. All data were obtained in decelerated flight (0 to -5g).

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INSTRUMENTATION

Inductance-type instruments were used to measure time histories of model normal and transverse acceleration, static and total pressure, deflection angle and hinge moments of each control, and model angle of attack. On the solid control, both high- and low-range instruments were used to measure hinge moments. The perforated control used only the high-range instrument. Response of the measuring and recording instrumentation was such that no correction to the recorded data was required at the frequencies encountered in the tests.

A Rawin set AN/GMD-1A recorded atmospheric data at all flight altitudes. Flight-path data were obtained from tracking radar, and a CW Doppler velocimeter was used to determine initial flight velocities. A visual flight record was obtained by photography.

TECHNIQUE

The technique employed in this investigation consisted of mechanically pulsing the controls as elevators so that their deflection varied sinusoidally with time. The pulsing frequency was varied from 5 cycles per second at a Mach number of 1.76 to $1\frac{1}{2}$ cycles per second at a Mach number of 0.7 in an attempt to obtain a constant 90° phase difference between the model pitching response and the control input. This phase difference allowed a more accurate separation of the effects of α and δ on the control hinge moment and model normal-force and pitching-moment results. The control pulsing amplitude was 5° with a variation of about $\pm\frac{1}{2}^{\circ}$ due to load deflection of the control linkage.

In addition to pitching oscillations, the model response included unwanted rolling and sideslip oscillations. This technique resulted in a continuous measurement of hinge moments for each control at varying combinations of control deflection, angle of sideslip, and angle of attack. These data are presented in table II and sample sections of the telemeter record are shown in figure 4.

ACCURACY

The following information is presented to indicate possible error in basic measurements. These values represent maximum error (±2 percent full-scale-instrument ranges) in evaluating isolated data. In computations involving differences (such as slope evaluations), possible errors in the component quantities can be considered to be about one-half as large as those indicated except as noted otherwise.

Quantity	Error
Control deflection, deg	±0.20
Model angle of attack, deg	
Maximum error	±(0.60 ± 0.50)
Difference error	±0.30
Model normal acceleration, g units	±1.0
High-range hinge moment, solid control, ft-lb . . .	±0.116
Low-range hinge moment, solid control, ft-lb	±0.040
Hinge moment, perforated control, ft-lb	±0.116
Model transverse acceleration, g units	±0.40
Normal acceleration at nose of model, g units . . .	±0.48

Error in Mach number is estimated to be less than ±0.02. Errors in dynamic pressure are estimated to be less than 5 percent.

Assuming probable errors of ±1 percent of full-scale-instrument range for the hinge-moment, angle-of-attack, and control-deflection data resulted in the following root-mean-square errors in hinge-moment results:

Mach number	Root-mean-square errors in -			
	$\frac{\Delta C_h}{\Delta \delta}$	$\frac{\Delta C_h}{\Delta \alpha}$	$\left(\frac{\Delta C_h}{\Delta \delta}\right)_p$	$\left(\frac{\Delta C_h}{\Delta \alpha}\right)_p$
0.71	±0.0011	±0.0006	±0.0035	±0.0019
.81	±.0008	±.0011	±.0026	±.0034
.91	±.0006	±.0008	±.0017	±.0024
.98	±.0006	±.0006	±.0026	±.0016
1.02	±.0005	±.0005	±.0014	±.0013
1.12	±.0006	±.0005	±.0015	±.0016
1.21	±.0006	±.0009	±.0014	±.0029
1.30	±.0018	±.0071	±.0017	±.0049
1.40	±.0020	±.0181	±.0021	±.0146
1.50	±.0016	±.0326	±.0017	±.0249
1.61	±.0011	±.0170	±.0012	±.0113
1.72	±.0008	±.0028	±.0007	±.0022
1.77	±.0004	±.0013	±.0004	±.0013

CORRECTIONS

Hinge-Moment Data

Hinge-moment measurements were corrected for zero load friction and inertia effects caused by the pulsing motion. These corrections were about 1/2 percent and 3/4 percent of the full-scale ranges of the hinge-moment instruments for the perforated and solid control, respectively. No attempt was made to determine the extent that flight airloads increased the bearing friction of the control and, hence, affected the measured control hinge moments.

Measured values of control deflection were adjusted to remove load deflection of the control system out to the inboard end of the control surfaces. However, no measurements or calculations were completed to determine control aeroelastic effects.

As previously mentioned, the model response included unwanted rolling and sideslip oscillations. Although the effects of rolling on the hinge moments are believed negligible, the sideslip was estimated to have an effect at subsonic speeds. By treating the sideslip as a change in sweep and using the expressions of reference 6, the following effects were indicated at subsonic speeds. Hinge moments on the solid control are increased about 1.8 percent per degree of positive sideslip and decreased about 2.0 percent per degree of negative sideslip. Hinge moments on the perforated control are increased about 1.8 percent per degree of negative sideslip and decreased about 2.0 percent per degree of positive sideslip. At supersonic speeds, the angles of sideslip experienced in the present test usually were less than $\pm 1^{\circ}$. Again, treating sideslip as a change in sweep, linearized-theory expressions were obtained from references 7 and 8 which indicated the effects of sideslip on values of $\Delta C_h/\Delta\delta$ to be negligible. In view of the small magnitude of sideslip, it is believed that the same result would apply to the effects of sideslip on hinge moments due to angle of attack and out of trim. Thus, although the subsonic hinge moments were adjusted to account for sideslip effects, no corrections were applied to the supersonic-hinge-moment data.

Normal-Force and Pitching-Moment Data

The effects of sideslip on model normal force and pitching moment were investigated and found to be negligible since the loss on one wing or control surface would be compensated by the gain of the opposite wing panel or control surface.

No aeroelastic corrections were applied to the measured data. It is believed that the rolling of the model had no effect on measured normal force or pitching moments.

ANALYSIS OF DATA

Hinge Moments

Although some nonlinearities were evident in the hinge-moment data, the exact form of these nonlinearities was not apparent. Therefore, the following linear analysis was used. The hinge-moment data were plotted as functions of α and δ as shown in figure 5. In figure 5(a), the curve connecting the data points represents the measured hinge-moment data. The straight-line curves connecting points of equal angle of attack on the measured data curve were constructed by assuming C_h to have a linear variation with δ at individual angles of attack; thus, some indication of the separate effects of δ on hinge moments was obtained. Similarly, in figure 5(b), straight-line curves connecting points of equal δ were constructed by assuming C_h to have a linear variation with α at individual control-surface deflections. This gave an indication of the effects of α on hinge moment.

Normal Force

Total normal force on the model was measured by means of a normal accelerometer. This total force was composed of forces due to angle of attack, control deflection, and out of trim. As in the analysis of the hinge-moment data, the model normal-force data were assumed to vary linearly with angle of attack and control deflection. In addition to determining the normal-force results by the same method used in reducing the hinge-moment data, a least-squares method was used in which the data were fitted to the following equation:

$$C_N = \frac{\Delta C_N}{\Delta \alpha} \alpha + \frac{\Delta C_N}{\Delta \delta_{av}} \delta_{av} + \left(C_N\right)_o$$

Pitching Moments

The pitching moments were calculated from the pitch acceleration of the model as determined from the readings of two normal accelerometers at separate locations along the model longitudinal axis. These pitching moments were analyzed by the same two methods described for the normal-force results. The following equation was used in the least-squares approach.

$$\frac{I_Y \ddot{\theta}}{57.3 q \bar{c} S} = \frac{\Delta C_m}{\Delta \alpha} \alpha + \frac{\Delta C_m}{\Delta \delta_{av}} \delta_{av} + \left(C_m\right)_o$$

Note that a pitch-damping term was not included in this equation. Since the lag of α behind δ was about one-fourth of a cycle at most Mach numbers, pitch damping was in phase with and became a part of the term $\frac{\Delta C_m}{\Delta \delta_{av}} \delta_{av}$. This prevented accurate values of control pitching moments from being obtained.

RESULTS AND DISCUSSION

Table II presents time histories of the reduced data obtained at various Mach numbers in this investigation. The measured responses of control hinge moment (both controls), model normal force, and model pitching moment are tabulated in coefficient form along with the variables angle of attack, control deflection, and angle of sideslip. These values are intended to supplement the plotted data.

Hinge Moments

A visual inspection of the telemeter record (reproduced in part in fig. 4) indicated that certain irregularities in the hinge-moment traces were present at several Mach numbers. These irregularities almost always occurred at or near peak control deflections (see, for example, fig. 5) and were inconsistent in form and direction (i.e., at some Mach numbers the first effect was an increase in hinge moments, whereas at other Mach numbers the effect first resulted in decreased hinge moments). Very slight irregularities were first noticed at about $M = 1.5$ for one control only and at negative deflections only. As Mach number decreased with increasing time, the irregularities became more pronounced until at about $M = 1.2$ the effect was obtained near both positive and negative deflection peaks and for both controls. Although no explanation of these irregularities was obtained and it is not definitely known whether they are aerodynamic or otherwise, it is believed that the explanation probably is not aerodynamic. Therefore, these data were not considered when the aerodynamic hinge moments were evaluated and values of $\Delta C_h/\Delta\alpha$ and $\Delta C_h/\Delta\delta$ were obtained at times when these irregularities were not evident.

The incremental slopes $\Delta C_h/\Delta\delta$ and $\Delta C_h/\Delta\alpha$ are presented as a function of Mach number in figures 6 and 7, respectively. Because of the assumption of linearity, these values represent average slopes over the measured ranges of α and δ which are indicated in the figures. The reader is cautioned against casually applying these results to different ranges of α and δ since nonlinearities may be present which could result in substantial errors.

Values of $\Delta C_h/\Delta\delta$ (fig. 6) are negative at all Mach numbers tested. Negative values indicate the controls are statically stable with control deflection (the center of pressure of the control deflection loading is behind the hinge lines). The variations of $\Delta C_h/\Delta\delta$ with Mach number are not unusual except for the trend to more negative values at the higher Mach numbers. This trend is not predicted by the theoretical results presented in figure 6 which were calculated for the solid control with the aid of linearized-theory expressions obtained from references 7 and 8. These calculations ignored the presence of the fuselage. In this comparison, the differences between theory and experiment are magnified by the nearness of the center of pressure to the hinge line. It has been suggested that the experimental variation in $\Delta C_h/\Delta\delta$ at the higher Mach numbers is primarily the result of changes in deflection range rather than a Mach number effect. (Note the indicated deflection ranges in fig. 6.)

The $\Delta C_h/\Delta\delta$ data at Mach numbers up to 1.1 which were obtained at $\alpha = -4$ indicate no appreciable effect of the control perforations. However, some of the data for $\alpha = 0$ and Mach numbers above 1.3 show that under these conditions the perforations resulted in a more closely balanced control with respect to deflection loads.

Values of $\Delta C_h/\Delta\alpha$ presented in figure 7 are less than ±0.01 except at $M = 1.3$ for the solid control. Data between the Mach numbers of 1.3 and 1.7 are not presented because the very small angle-of-attack ranges resulted in large probable errors. (See section entitled "Accuracy.")

The effect of the perforations on $\Delta C_h/\Delta\alpha$ is small and is seen to be dependent upon the Mach number region. At supersonic Mach numbers, the $\Delta C_h/\Delta\alpha$ values are displaced in a positive direction, whereas at subsonic speeds the opposite result was obtained.

Values of $\Delta C_h/\Delta\alpha$ also were measured at $\delta = 2^{\circ}$. No significant differences were obtained with respect to the data at $\delta = 0^{\circ}$.

Although no direct hinge-moment comparisons have been made with other configurations because the author could find no applicable comparison data, it should be noted that the measured hinge moments of the present investigation were small throughout the flight (never greater than ±2.2 foot-pounds). This is indicated also by the values of $\Delta C_h/\Delta\delta$ and $\Delta C_h/\Delta\alpha$ in figures 6 and 7. Although these values may not appear especially low, it should be remembered that they are based upon the control moment area behind the hinge line which exaggerates their magnitude relative to coefficients for controls hinged forward of the 40 percent chord.

Normal Force

Figure 8 presents a sample variation of normal-force coefficient with control deflection at various angles of attack. By use of this type of plot and the assumption that normal-force coefficient varied linearly with both angle of attack and control deflection, values of $\Delta C_N/\Delta\alpha$ and $\Delta C_N/\Delta\delta_{av}$ were obtained.

Values of $\Delta C_N/\Delta\delta_{av}$ are presented in figure 9 for $\alpha = 0$. These values represent the average effect of both controls. Also shown are similar values which were obtained by means of a least-squares analysis. The differences in the results of the two methods are a measure of the nonlinearities of the data (i.e., the change of $\Delta C_N/\Delta\delta_{av}$ with α) since the least-squares data represent a mean or average slope for all angles of attack experienced at a particular Mach number. The trend of $\Delta C_N/\Delta\delta_{av}$ with Mach number is typical. However, the general level of the curve is somewhat less than indicated by the linearized-theory values which were obtained from reference 7 for the solid control and are shown in figure 9. In addition to the usual limitations of the linearized theory, a small part of this difference is believed to be due to the flexibility of the controls (in twist) and to the perforations in one control which the theory does not consider.

Values of $\Delta C_N/\Delta\alpha$ are presented in figure 10 for $\delta = 0$. Also shown are values of $\Delta C_N/\Delta\alpha$ which were obtained in a least-squares type of analysis. The shape of the faired curve is regular and good agreement is obtained with the comparison values, which were computed from an unpublished extension to the linearized theory reported in reference 9 for a rigid wing-body combination and modified to include wing aeroelastic effects by a method similar to that reported in reference 10.

Pitching Moments

Figure 11 presents the variation of $\Delta C_m/\Delta\alpha$ with Mach number. The curve is typical with increasing values up to transonic speeds, a leveling off at near-sonic speeds, and decreasing values at supersonic speeds.

Although values of $\Delta C_m/\Delta\delta_a$ were obtained, they are not presented since they represent a mixture of control pitching moments and pitch damping moments as explained in the section entitled "Analysis of Data." However, good estimates of control pitching effectiveness at supersonic speeds can be obtained by assuming that the faired normal-force results are acting at the control center of area.

CONCLUSIONS

The results of a rocket-model investigation of the hinge moments on a constant-chord, inboard, trailing-edge control with 67 percent overhang balance on a 52.5° swept and tapered wing between the Mach numbers of 0.7 and 1.8 led to the following conclusions:

1. Control hinge moments were small throughout the speed range for all combinations of angle of attack and control deflection tested.

2. The addition of a single row of holes near the control trailing edge resulted in no measureable effects on values of hinge moments due to control deflection except for angles of attack near zero at Mach numbers greater than 1.3 where a small reduction in control restoring moments was attributed to the perforations.

3. The addition of the control trailing-edge perforations resulted only in small changes in values of hinge moments due to angle of attack.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., May 14, 1957.

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TABLE I

PHYSICAL CONSTANTS OF MODEL

Model weight, lb	119.4
Model pitch inertia, slug-ft^2	17.28
Model c.g.	Station 58.9
Wing area:	
Total, sq ft	2.493
Exposed, sq ft	1.671
Wing M.A.C., ft	1.056
Leading edge of wing M.A.C.	Station 66.8
Wing sweepback:	
Leading edge, deg	56.7
Quarter-chord line, deg	52.5
Trailing edge, deg	32.5
Area of solid control, sq ft	0.1177
Area of perforated control, sq ft	0.1142
$2M'$, ft^3	0.00678
$2M'_p$, ft^3	0.00653
Sweepback of control hinge axis, deg	32.5

TABLE II.- TIME HISTORIES OF TEST DATA

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β	Corrected for β: C_h	Corrected for β: $(C_h)_p$
M = 0.71										
19.90	-8.89	-1.84	-1.80	-0.0609	-0.0453	-0.5460	0.3280	4.21	-0.0425	-0.0636
19.92	-7.71	-2.76	-2.73	-.0386	-.0338	-.5009	.3259	4.55	-.0316	-.0419
19.94	-6.10	-3.57	-3.59	-.0351	-.0281	-.4103	.2885	4.82	-.0262	-.0384
19.96	-4.57	-4.28	-4.33	-.0283	-.0189	-.3088	.2553	4.76	-.0176	-.0303
19.98	-3.22	-4.78	-4.86	-.0144	-.0099	-.2147	.1938	4.24	-.0093	-.0155
20.00	-1.29	-5.06	-5.14	-.0162	.0004	-.1214	.1416	3.62	.0004	-.0173
20.02	1.08	-5.17	-5.26	-.0144	.0074	-.0144	.0740	2.81	.0071	-.0151
20.04	2.64	-5.13	-5.36	-.0100	.0145	.0809	0	1.88	.0141	-.0103
20.06	4.40	-4.82	-5.04	-.0100	.0319	.1618	-.0182	.73	.0315	-.0101
20.08	5.88	-4.35	-4.56	-.0012	.0369	.2407	-.0562	-.29	.0371	-.0012
20.10	7.11	-3.65	-3.84	-.0031	.0439	.3268	-.1069	-1.57	.0450	-.0030
20.12	8.15	-2.89	-3.08	-.0049	.0467	.3820	-.1287	-2.48	.0487	-.0047
20.14	8.82	-1.93	-2.06	-.0049	.0482	.4217	-.1321	-3.45	.0512	-.0046
20.16	9.32	-1.04	-1.13	-.0102	.0475	.4430	-.1383	-4.26	.0513	-.0096
20.18	9.28	0	-.08	-.0121	.0463	.4562	-.1401	-5.06	.0507	-.0113
20.20	9.06	.94	.88	-.0157	.0440	.4454	-.1482	-5.87	.0491	-.0144
20.22	8.46	2.05	2.02	-.0141	.0339	.4304	-.1616	-6.33	.0382	-.0129
20.24	7.61	2.83	2.85	-.0320	.0265	.3793	-.1507	-6.65	.0298	-.0291
20.26	6.40	3.40	3.47	-.0429	.0190	.3197	-.1262	-6.55	.0215	-.0391
20.28	5.26	3.97	4.07	-.0429	.0125	.2603	-.1216	-6.25	.0140	-.0392
20.30	3.93	4.40	4.52	-.0507	.0036	.1839	-.0750	-5.76	.0040	-.0466
20.32	2.31	4.81	4.93	-.0581	-.0024	.0868	-.0078	-4.80	-.0026	-.0541
20.34	.62	4.99	5.12	-.0711	-.0166	.0298	0	-3.77	-.0177	-.0672
20.36	-.91	4.94	5.21	-.0690	-.0195	-.0367	.0252	-2.75	-.0205	-.0662
20.38	-2.50	4.73	5.00	-.0672	-.0286	-.1088	.0471	-2.04	-.0296	-.0651
20.40	-4.27	4.45	4.71	-.0712	-.0333	-.2039	.0980	-1.19	-.0340	-.0698
20.42	-5.73	3.98	4.23	-.0790	-.0404	-.2991	.1365	-.38	-.0406	-.0783
20.44	-7.27	3.34	3.59	-.0900	-.0485	-.3856	.1742	.38	-.0482	-.0906
20.46	-8.38	2.76	2.97	-.0847	-.0582	-.4679	.2400	1.15	-.0571	-.0863
20.48	-9.35	1.95	2.13	-.0904	-.0597	-.5424	.2900	1.76	-.0580	-.0931
20.50	-10.09	1.12	1.27	-.0812	-.0565	-.5838	.3108	2.53	-.0544	-.0849
20.52	-10.35	.29	.41	-.0780	-.0561	-.6094	.3318	3.39	-.0533	-.0828
20.54	-10.13	-.59	-.51	-.0628	-.0547	-.6052	.3333	4.11	-.0515	-.0676
20.56	-9.62	-1.57	-1.51	-.0629	-.0548	-.5708	.3055	4.80	-.0511	-.0558
20.58	-8.68	-2.44	-2.40	-.0538	-.0478	-.5445	.3144	5.30	-.0461	-.0593
20.60	-7.40	-3.32	-3.31	-.0408	-.0368	-.4677	.2960	5.86	-.0358	-.0455
M = 0.81										
16.83	-4.61	-0.92	-0.85	-0.0292	-0.0259	-0.2826	0.1873	5.88	-0.0220	-0.0325
16.85	-4.39	-2.01	-1.96	-.0305	-.0198	-.2789	.1941	5.47	-.0183	-.0337
16.87	-3.73	-3.03	-3.01	-.0243	-.0115	-.2626	.1920	4.78	-.0107	-.0265
16.89	-3.21	-3.99	-4.01	-.0205	-.0054	-.2437	.1930	3.88	-.0051	-.0220
16.91	-2.68	-4.69	-4.73	-.0168	.0003	-.2063	.1814	2.72	.0003	-.0176
16.93	-1.93	-5.06	-5.14	-.0168	.0040	-.1729	.1723	1.50	.0039	-.0172
16.95	-1.36	-5.19	-5.28	-.0194	.0084	-.1444	.1481	.43	.0083	-.0195
16.97	-.64	-5.16	-5.38	-.0238	.0094	-.1106	.1225	-.86	.0095	-.0233
16.99	.06	-4.78	-5.00	-.0238	.0221	-.0889	.1380	-2.00	.0229	-.0231
17.01	.50	-4.17	-4.38	-.0213	.0211	-.0134	.0762	-3.11	.0223	-.0203
17.03	1.18	-3.30	-3.50	-.0214	.0256	.0240	.0488	-4.37	.0255	-.0201
17.05	1.73	-2.25	-2.40	-.0239	.0254	.0739	.0210	-5.41	.0280	-.0221
17.07	2.35	-1.18	-1.28	-.0266	.0274	.1057	-.0040	-6.02	.0306	-.0244
17.09	2.83	.04	-.05	-.0241	.0260	.1400	-.0300	-6.43	.0293	-.0220
17.11	3.21	1.14	1.07	-.0254	.0238	.1834	-.0320	-6.41	.0268	-.0232
17.13	3.38	2.18	2.15	-.0256	.0194	.1997	-.0693	-6.07	.0219	-.0233
17.15	3.53	3.13	3.14	-.0243	.0141	.2053	-.0738	-5.43	.0156	-.0225
17.17	3.37	3.94	4.03	-.0269	.0107	.1904	-.0818	-4.31	.0115	-.0252
17.19	2.93	4.62	4.73	-.0310	.0060	.1638	-.0780	-3.10	.0063	-.0296
17.21	2.13	4.89	5.00	-.0336	-.0017	.1443	-.0676	-1.92	-.0018	-.0326
17.23	1.39	5.03	5.20	-.0379	-.0070	.1077	-.0554	-.92	-.0071	-.0374
17.25	.47	5.00	5.28	-.0380	-.0143	.0499	-.0215	.03	-.0143	-.0380
17.27	-.63	4.74	4.99	-.0276	-.0150	-.0196	.0148	1.10	-.0147	-.0281
17.29	-1.83	4.27	4.49	-.0316	-.0270	-.3123	.0450	1.92	-.0262	-.0326
17.31	-2.97	3.59	3.79	-.0329	-.0275	-.1399	.0740	2.73	-.0264	-.0345
17.33	-4.09	2.70	2.89	-.0369	-.0308	-.2024	.1083	3.50	-.0292	-.0392
17.35	-4.76	1.77	1.91	-.0356	-.0303	-.2518	.1493	4.34	-.0284	-.0383
17.37	-5.31	.70	.82	-.0337	-.0304	-.3113	.1992	4.91	-.0283	-.0390
17.39	-5.33	-.38	-.32	-.0318	-.0267	-.3196	.1954	5.30	-.0247	-.0350
17.41	-5.23	-1.49	-1.41	-.0372	-.0267	-.3425	.2219	5.54	-.0246	-.0412
17.43	-4.89	-2.61	-2.55	-.0359	-.0188	-.3253	.2143	5.40	-.0174	-.0396
17.45	-4.18	-3.55	-3.53	-.0319	-.0134	-.2705	.1809	5.01	-.0124	-.0349
17.47	-3.23	-4.27	-4.30	-.0226	-.0063	-.2454	.1898	4.43	-.0059	-.0245

TABLE II.- TIME HISTORIES OF TEST DATA - Continued

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β	Corrected for β: C_h	Corrected for β: $(C_h)_p$
M = 0.91										
14.22	-2.32	-3.48	-3.45	-0.0296	-0.0032	-0.1681	0.1411	-0.03	-0.0032	-0.0296
14.24	-2.10	-4.36	-4.38	-.0288	.0013	-.1614	.1404	-1.47	.0013	-.0282
14.26	-1.76	-5.02	-5.06	-.0297	.0094	-.1362	.1144	-2.52	.0098	-.0286
14.28	-1.28	-5.33	-5.37	-.0316	.0218	-.1164	.1162	-3.66	.0232	-.0299
14.30	-.62	-5.33	-5.48	-.0505	.0228	-.0712	.0886	-4.60	.0249	-.0472
14.32	.07	-4.87	-5.04	-.0351	.0244	-.0346	.0744	-5.09	.0267	-.0326
14.34	.84	-4.05	-4.23	-.0209	.0221	.0222	.0369	-5.22	.0243	-.0194
14.36	1.65	-2.93	-3.10	-.0238	.0231	.0789	0	-4.93	.0252	-.0222
14.38	2.46	-1.63	-1.73	-.0211	.0246	.1309	-.0363	-4.20	.0265	-.0198
14.40	3.12	-.31	-.35	-.0156	.0216	.1734	-.0690	-3.21	.0228	-.0149
14.42	3.32	1.00	.93	-.0063	.0177	.2077	-.0960	-2.08	.0183	-.0061
14.44	3.40	2.46	2.44	-.0035	.0128	.2171	-.1045	-1.06	.0130	-.0034
14.46	3.03	3.35	3.38	-.0044	.0076	.2108	-.1143	.04	.0076	-.0044
14.48	2.56	4.19	4.28	-.0063	.0065	.1795	-.0910	1.20	.0064	-.0064
14.50	1.69	4.82	4.91	-.0139	-.0102	.1328	-.0763	2.07	-.0099	-.0144
14.52	.68	5.12	5.21	-.0150	-.0305	.0783	-.0609	2.92	-.0292	-.0158
14.54	-.45	5.22	5.44	-.0141	-.0326	.0136	-.0181	3.60	-.0309	-.0149
14.56	-1.82	4.75	4.99	-.0240	-.0286	-.0645	.0381	4.10	-.0269	-.0258
14.58	-2.67	4.25	4.46	-.0260	-.0272	-.1258	.0606	4.21	-.0256	-.0280
14.60	-3.50	3.30	3.51	-.0337	-.0295	-.1810	.1008	4.23	-.0277	-.0363
14.62	-4.18	2.28	2.46	-.0398	-.0323	-.2290	.1284	4.01	-.0304	-.0427
14.64	-4.54	1.04	1.18	-.0428	-.0328	-.2731	.1656	3.75	-.0310	-.0457
14.66	-4.73	-.21	-.11	-.0389	-.0293	-.2946	.1852	3.21	-.0279	-.0411
14.68	-4.69	-1.48	-1.41	-.0349	-.0213	-.3023	.2006	2.45	-.0205	-.0364
14.70	-4.39	-2.66	-2.61	-.0321	-.0156	-.3015	.2040	1.68	-.0152	-.0330
14.72	-3.86	-3.69	-3.68	-.0322	-.0079	-.2800	.1925	.74	-.0078	-.0326
14.74	-3.13	-4.50	-4.52	-.0293	-.0053	-.2449	.1829	-.29	-.0053	-.0292
14.76	-2.17	-5.04	-5.10	-.0274	.0021	-.1917	.1807	-1.30	.0021	-.0269
14.78	-1.15	-5.26	-5.33	-.0236	.0084	-.1321	.1627	-2.32	.0087	-.0228
14.80	-.20	-5.27	-5.45	-.0426	.0160	-.0562	.0889	-3.25	.0169	-.0406
M = 0.97										
13.02	6.48	-1.27	-1.30	0.0064	0.0670	0.3774	-0.1854	-3.85	0.0717	0.0060
13.04	6.15	.23	.19	-.0028	.0405	.3655	-.1853	-4.52	.0439	-.0026
13.06	5.11	1.72	1.71	-.0160	.0225	.3087	-.1608	-4.65	.0174	-.0149
13.08	3.50	2.95	2.97	-.0264	.0019	.2298	-.1317	-4.28	.0020	-.0248
13.10	1.55	3.93	4.02	-.0440	-.0272	.1242	-.0744	-3.41	-.0289	-.0418
13.12	-.64	4.61	4.70	-.0966	-.0792	.0223	-.0251	-2.27	-.0823	-.0933
13.14	-2.56	4.91	5.01	-.0872	-.0746	-.0997	.0415	-1.19	-.0761	-.0856
13.16	-4.37	4.76	5.01	-.0974	-.0828	-.2172	.1121	.36	-.0823	-.0980
13.18	-5.76	4.24	4.46	-.1001	-.0877	-.3024	.1598	1.55	-.0856	-.1028
13.20	-6.80	3.40	3.64	-.0986	-.0716	-.3771	.2109	2.69	-.0687	-.1033
13.22	-7.09	2.25	2.46	-.0849	-.0569	-.3900	.2142	3.81	-.0538	-.0908
13.24	-6.63	.95	1.11	-.0646	-.0459	-.3910	.2355	4.73	-.0428	-.0703
13.26	-5.47	-.37	-.26	-.0459	-.0321	-.3362	.2111	5.15	-.0298	-.0504
13.28	-3.90	-1.82	-1.76	-.0265	-.0120	-.2379	.1617	4.88	-.0112	-.0289
13.30	-2.19	-3.07	-3.01	-.0113	.0092	-.1315	.1010	3.97	.0087	-.0121
13.32	-.11	-4.05	-3.99	.0176	.0651	-.0422	.0558	2.48	.0626	.0184
13.34	1.42	-4.73	-4.71	.0183	.0555	.0527	.0091	.89	.0547	.0186
13.36	2.53	-5.04	-5.04	.0145	.0584	.1173	-.0126	-1.13	.0595	.0142
13.38	3.53	-5.01	-5.15	.0073	.0615	.1834	-.0584	-2.52	.0642	.0070
13.40	4.13	-4.47	-4.57	.0017	.0745	.2211	-.0938	-4.21	.0802	.0016
13.42	4.14	-3.56	-3.64	-.0049	.0818	.2376	-.1035	-5.50	.0904	-.0045
13.44	3.92	-2.29	-2.35	-.0082	.0741	.2345	-.1024	-6.32	.0832	-.0075
13.46	3.62	-.83	-.83	-.0214	.0554	.2113	-.0970	-6.19	.0621	-.0196
13.48	3.01	.65	.62	-.0157	.0358	.1881	-.0879	-5.46	.0395	-.0145

[redacted]

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TABLE II.- TIME HISTORIES OF TEST DATA - Continued

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
M = 1.02								
12.29	5.24	3.85	3.91	-0.0278	-0.0172	0.3392	-0.1842	-2.36
12.30	4.44	4.28	4.37	-.0364	-.0254	.3003	-.1757	-2.46
12.31	3.56	4.66	4.75	-.0456	-.0337	.2324	-.1214	-2.53
12.32	2.32	4.94	5.05	-.0521	-.0424	.1858	-.1154	-2.46
12.33	1.05	5.07	5.20	-.0555	-.0526	.1145	-.0636	-2.32
12.34	.14	4.99	5.25	-.0914	-.0829	.0540	-.0406	-2.12
12.35	-1.24	4.73	4.98	-.1040	-.0903	-.0173	-.0050	-1.84
12.36	-2.42	4.50	4.72	-.0772	-.0764	-.0868	.0371	-1.49
12.37	-3.55	4.09	4.30	-.0824	-.0784	-.1466	.0639	-1.27
12.38	-4.68	3.77	3.99	-.0915	-.0791	-.2199	.1196	-.70
12.39	-5.34	3.17	3.40	-.0935	-.0760	-.2754	0	-.14
12.40	-6.30	2.49	2.70	-.0894	-.0657	-.3224	.1696	.33
12.41	-7.01	1.82	2.02	-.0851	-.0533	-.3828	.2220	.93
12.42	-7.36	1.02	1.20	-.0736	-.0401	-.4054	.2144	1.51
12.43	-7.63	.28	.45	-.0632	-.0310	-.4363	.2488	1.79
12.44	-7.70	-.49	-.36	-.0540	-.0218	-.4501	.2630	2.12
12.45	-7.43	-1.33	-1.22	-.0417	-.0125	-.4382	.2625	2.49
12.46	-7.12	-2.08	-1.99	-.0325	-.0033	-.4201	.2586	2.82
12.47	-6.31	-2.85	-2.79	-.0186	.0024	-.3991	.2525	3.05
12.48	-5.86	-3.46	-3.44	-.0065	.0122	-.3777	.2529	3.17
12.49	-4.88	-4.05	-4.01	-.0037	.0195	-.3069	.2050	3.21
12.50	-4.02	-4.50	-4.51	.0034	.0278	-.2451	.1707	3.11
12.51	-2.90	-4.85	-4.85	.0128	.0407	-.1909	.1458	2.97
12.52	-1.59	-5.01	-5.01	.0256	.0551	-.1145	.0985	2.61
12.53	-.60	-5.11	-5.10	.0398	.0837	-.0372	.0825	2.24
12.54	.75	-5.07	-5.21	.0365	.0805	.0227	.0225	1.85
12.55	1.80	-4.95	-5.09	.0345	.0678	.0785	.0069	1.33
12.56	2.93	-4.59	-4.74	.0374	.0762	.1357	-.0258	.96
12.57	4.09	-4.15	-4.28	.0381	.0855	.2068	-.0852	.34
12.58	4.95	-3.58	-3.69	.0389	.0885	.2577	-.0988	-.14
12.59	5.81	-3.05	-2.95	.0325	.0821	.3070	-.2907	-.71
12.60	6.32	-2.25	-2.31	.0260	.0744	.3302	-.1658	-1.25
12.61	6.79	-1.46	-1.30	.0168	.0664	.3755	-.1694	-1.47
12.62	6.96	-.70	-.72	.0095	.0539	.4039	-.1959	-1.97
12.63	7.04	.12	.08	.0050	.0409	.4153	-.2059	-2.35
12.64	6.89	.90	.88	-.0056	.0295	.4153	-.2096	-2.76
12.65	6.57	1.68	1.64	-.0073	.0186	.4058	-.2205	-3.10
12.66	5.98	2.54	2.55	-.0153	.0076	.3684	-.2025	-3.40
12.67	5.38	3.12	3.15	-.0207	-.0025	.3385	-.1826	-3.57
12.68	4.47	3.71	3.79	-.0327	-.0132	.2842	-.1609	-3.58
12.69	3.50	4.18	4.27	-.0373	-.0250	.2550	-.1385	-3.45

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
M = 1.12								
10.61	-1.07	3.58	3.74	-0.0711	-0.0718	-0.0162	0.0145	-1.19
10.62	-1.84	2.80	3.01	-.0587	-.0462	-.0646	.0319	-1.00
10.63	-2.70	1.98	2.19	-.0577	-.0541	-.1105	.0536	-.72
10.64	-3.35	1.01	1.19	-.0517	-.0260	-.1581	.0915	-.39
10.65	-3.91	.08	.27	-.0467	-.0130	-.1916	.0996	-.12
10.66	-4.54	.85	-.69	-.0517	.0015	-.2296	.1347	.29
10.67	-4.85	-1.75	-1.61	-.0184	.0175	-.2610	.1580	.59
10.68	-5.01	-2.64	-2.51	-.0047	.0320	-.2766	.1739	.89
10.69	-5.05	-3.44	-3.35	.0078	.0430	-.2851	.1854	1.16
10.70	-4.85	-4.14	-4.08	.0202	.0544	-.2757	.1755	1.30
10.71	-4.46	-4.66	-4.62	.0268	.0661	-.2698	.1819	1.50
10.72	-4.00	-4.99	-4.97	.0340	.0745	-.2537	.1600	1.60
10.73	-3.44	-5.15	-5.13	.0388	.0755	-.2047	.1471	1.64
10.74	-2.68	-5.14	-5.29	.0441	.0652	-.1605	.1162	1.64
10.75	-1.98	-4.94	-5.11	.0441	.0700	-.1152	.0953	1.61
10.76	-1.05	-4.46	-4.56	.0459	.0866	-.0726	.0758	1.54
10.77	.05	-3.88	-3.97	.0460	.0881	-.0179	.0390	1.33
10.78	.95	-3.15	-3.27	.0269	.05777	.0373	.0149	1.24
10.79	1.89	-2.30	-2.32	.0225	.0467	.0714	.0655	1.02
10.80	2.64	-1.37	-1.45	.0182	.0380	.1358	-.0580	.74
10.81	3.24	-.42	-.47	.0105	.0256	.1712	-.0691	.47
10.82	3.81	.53	.43	.0010	.0042	.2168	-.1084	.19
10.83	4.27	1.44	1.54	-.0091	-.0116	.2575	-.1150	-.05
10.84	4.51	2.35	2.28	-.0217	-.0301	.2659	-.1448	———
10.85	4.67	3.12	3.08	-.0327	-.0433	.2786	-.1548	-.61
10.86	4.65	3.86	3.88	-.0447	-.0565	.2754	-.1486	-.81
10.87	4.35	4.43	4.47	-.0507	-.0670	.2726	-.1605	-1.05
10.88	3.87	4.91	4.97	-.0618	-.0733	.2485	-.1446	-1.28
10.89	3.27	5.25	5.34	-.0666	-.0774	.2111	-.1228	-1.38
10.90	2.47	5.30	5.39	-.0657	-.0765	.1804	-.1085	-1.30
10.91	1.59	5.30	5.30	-.0622	-.0777	.1225	-.0629	-1.47
10.92	.95	4.76	4.96	-.0708	-.0854	.0809	-.0492	-1.52
10.93	-.08	4.31	4.70	-.0650	-.0895	.0315	-.0257	-1.39
10.94	-1.26	3.73	3.95	-.0840	-.0786	-.0512	.0202	-1.27
10.95	-1.99	3.00	3.24	-.0692	-.0516	-.0821	.0405	-1.02
10.96	-2.81	2.51	2.53	-.0665	-.0410	-.1413	.0895	-.85
10.97	-3.85	1.38	1.57	-.0600	-.0358	-.1825	.1105	-.44
10.98	-4.28	.42	.60	-.0342	-.0259	-.2257	.1315	-.11

TABLE II.- TIME HISTORIES OF TEST DATA - Continued

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
M = 1.21								
9.25	0.96	0.01	-0.10	0	0.0045	0.0708	-0.0247	0.31
9.26	1.28	1.10	.97	-.0088	-.0167	.0975	-.0325	.14
9.27	1.60	2.09	1.94	-.0205	-.0404	.1185	-.0455	.02
9.28	1.85	2.98	2.85	-.0351	-.0626	.1390	-.0625	-.21
9.29	1.84	3.87	3.80	-.0501	-.0805	.1560	-.0782	-.37
9.30	1.74	4.49	4.44	-.0641	-.0957	.1691	-.0953	-.45
9.31	1.74	4.73	4.71	-.0725	-.1036	.1596	-.0877	-.57
9.32	1.60	5.16	5.17	-.0781	-.1078	.1523	-.0935	-.74
9.33	1.27	5.11	5.22	-.0788	-.1050	.1304	-.0761	-.82
9.34	.94	4.84	5.00	-.0733	-.0973	.1028	-.0576	-.90
9.35	.43	4.33	4.45	-.0660	-.0896	.0774	-.0499	-.88
9.36	-.09	3.77	3.91	-.0609	-.0758	.0379	-.0170	-.85
9.37	-.70	2.90	3.08	-.0532	-.0513	.0007	.0031	-.76
9.38	-1.39	1.96	2.15	-.0456	-.0299	-.0381	.0245	-.69
9.39	-1.84	.97	1.15	-.0330	-.0129	-.0714	.0413	-.52
9.40	-2.30	.04	.23	-.0234	.0041	-.1129	.0765	-.40
9.41	-2.90	-.99	-.84	-.0097	.0212	-.1331	.0829	-.15
9.42	-3.16	-2.09	-1.91	.0001	.0390	-.1510	.0884	.06
9.43	-3.42	-3.05	-2.90	.0159	.0559	-.1817	.1228	.24
9.44	-3.47	-3.89	-3.78	.0329	.0727	-.1887	.1257	.41
9.45	-3.47	-4.42	-4.31	.0422	.0875	-.1865	.1265	.59
9.46	-3.17	-4.84	-4.75	.0527	.0981	-.1800	.1205	.71
9.47	-2.86	-5.11	-5.03	.0555	.1019	-.1683	.1181	.80
9.48	-2.54	-5.06	-5.16	.0571	.0881	-.1415	.0981	.89
9.49	-1.97	-4.77	-4.90	.0536	.0814	-.1130	.0854	.89
9.50	-1.43	-4.32	-4.45	.0528	.0823	-.0783	.0607	.91
9.51	-.93	-3.62	-3.71	.0424	.0806	-.0478	.0508	.85
9.52	-.33	-2.78	-2.86	.0253	.0588	.0031	.0108	.72
9.53	.21	-1.76	-1.85	.0094	.0304	.0279	.0059	.61
9.54	.72	-.71	-.77	.0053	.0187	.0733	-.0316	.48
9.55	1.29	.34	.23	.0007	.0003	.1041	-.0487	.31
9.56	1.61	1.38	1.24	-.0108	-.0228	.1351	-.0680	.16
9.57	1.79	2.32	2.18	-.0236	-.0460	.1522	-.0730	-.07
9.58	2.00	3.00	2.90	-.0393	-.0641	.1776	-.0967	-.27
M = 1.30								
7.83	-1.32	-4.16	-4.24	0.0513	0.0827	-0.0663	0.0534	0.28
7.84	-.86	-3.36	-3.41	.0310	.0697	-.0461	.0427	.30
7.85	-.43	-2.37	-2.41	.0074	.0450	-.0223	.0275	.25
7.86	-.13	-1.12	-1.18	-.0040	.0165	.0067	.0099	.25
7.87	.28	.08	-.05	-.0149	-.0138	.0351	-.0031	.20
7.88	.59	1.24	1.07	-.0257	-.0366	.0580	-.0234	.14
7.89	.78	2.50	2.36	-.0375	-.0548	.0702	-.0228	.08
7.90	.89	3.26	3.13	-.0518	-.0793	.0908	-.0459	.05
7.91	.99	3.98	3.88	-.0651	-.0965	.1053	-.0548	-.05
7.92	1.07	4.60	4.52	-.0783	-.1097	.1051	-.0574	-.11
7.93	.98	4.93	4.90	-.0874	-.1147	.1024	-.0590	-.19
7.94	.91	4.98	5.04	-.0772	-.1140	.0914	-.0531	-.27
7.95	.60	4.66	4.77	-.0739	-.0988	.0769	-.0463	-.34
7.96	.50	4.07	4.21	-.0654	-.0792	.0570	-.0337	-.35
7.97	.05	3.38	3.55	-.0537	-.0563	.0317	-.0192	-.37
7.98	-.38	2.45	2.60	-.0354	-.0390	.0024	.0028	-.38
7.99	-.70	1.31	1.48	-.0211	-.0122	-.0219	.0126	-.32
8.00	-1.14	.24	.44	-.0078	.0122	-.0445	.0225	-.27
8.01	-1.61	-.87	-.71	.0064	.0288	-.0753	.0489	-.20
8.02	-1.94	-1.99	-1.81	.0190	.0493	-.0919	.0588	-.13
8.03	-2.17	-3.06	-2.90	.0361	.0695	-.1112	.0739	-.02
8.04	-2.29	-3.93	-3.78	.0492	.0879	-.1241	.0849	.05
8.05	-2.24	-4.55	-4.43	.0615	.1039	-.1235	.0809	.14
8.06	-2.24	-4.93	-4.81	.0673	.1144	-.1236	.0848	.22
8.07	-2.05	-5.05	-5.09	.0671	.1119	-.1146	.0840	.27
8.08	-1.70	-4.83	-4.92	.0616	.0949	-.0974	.0726	.32
8.09	-1.42	-4.32	-4.40	.0514	.0864	-.0762	.0601	.35
8.10	-1.06	-3.58	-3.64	.0329	.0744	-.0488	.0435	.36
8.11	-.61	-2.62	-2.68	.0124	.0514	-.0240	.0274	.33
8.12	-.26	-1.55	-1.61	-.0031	.0224	.0070	.0016	.30
8.13	.19	-.36	-.42	-.0122	-.0026	.0344	-.0068	.27

TABLE II.- TIME HISTORIES OF TEST DATA - Continued

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
M = 1.40								
6.55	-1.54	-3.29	-3.12	0.0529	0.0793	-0.0710	0.0421	0.03
6.56	-1.49	-4.12	-3.97	.0661	.0968	-.0832	.0552	.06
6.57	-1.65	-4.71	-4.58	.0785	.1108	-.0915	.0647	.11
6.58	-1.59	-4.90	-4.79	.0809	.1133	-.0863	.0622	.12
6.59	-1.53	-4.78	-4.89	.0785	.0922	-.0751	.0540	.14
6.60	-1.26	-4.27	-4.38	.0639	.0827	-.0630	.0455	.10
6.61	-.90	-3.49	-3.57	.0429	.0674	-.0506	.0410	.13
6.62	-.67	-2.40	-2.47	.0190	.0438	-.0270	.0225	.13
6.63	-.35	-1.27	-1.32	-.0021	.0179	-.0031	.0056	.13
6.64	-.03	.03	-.06	-.0220	-.0126	.0156	0	.09
6.65	.40	1.44	1.31	-.0318	-.0364	.0390	-.0186	.05
6.66	.57	2.60	2.48	-.0489	-.0587	.0532	-.0262	.01
6.67	.84	3.50	3.41	-.0643	-.0827	.0659	-.0329	-.01
6.68	.94	4.29	4.21	-.0813	-.1014	.0767	-.0427	-.06
6.69	.84	4.77	4.71	-.0888	-.1108	.0738	-.0405	-.08
6.70	.75	4.79	4.87	-.0902	-.1123	.0768	-.0493	-.11
6.71	.63	4.60	4.72	-.0850	-.1007	.0641	-.0381	-.12
6.72	.35	4.20	4.35	-.0711	-.0773	.0544	-.0360	-.14
6.73	.20	3.24	3.42	-.0554	-.0545	.0340	-.0240	-.17
6.74	-.20	2.24	2.41	-.0344	-.0322	.0136	-.0111	-.17
6.75	-.53	1.13	1.30	-.0149	-.0062	-.0054	.0013	-.19
6.76	-.93	.06	.11	.0036	.0190	-.0289	.0215	-.14
6.77	-1.09	1.42	-1.24	.0237	.0453	-.0454	.0278	-.12
6.78	-1.25	2.51	-2.34	.0424	.0643	-.0678	.0455	-.07
6.79	-1.50	3.57	-3.44	.0592	.0825	-.0799	.0552	0
6.80	-1.74	4.31	-4.18	.0712	.1019	-.0852	.0580	.06
6.81	-1.67	4.76	-4.65	.0798	.1113	-.0867	.0576	.08
6.82	-1.57	4.87	-4.92	.0792	.1114	-.0823	.0594	.14
M = 1.50								
5.49	-0.33	-1.392	-1.49	0.0044	0.0138	-0.0094	0.0107	0.14
5.50	.07	-.08	-.20	-.0147	-.0123	.0144	-.0066	.13
5.51	.28	1.22	1.09	-.0359	-.0353	.0293	-.0120	.15
5.52	.51	2.53	2.39	-.0520	-.0602	.0465	-.0252	.16
5.53	.70	3.45	3.36	-.0689	-.0810	.0579	-.0306	.13
5.54	.73	4.33	4.25	-.0811	-.0956	.0695	-.0407	.11
5.55	.73	4.63	4.58	-.0886	-.1011	.0673	-.0370	.10
5.56	.68	4.67	4.77	-.0856	-.0987	.0653	-.0385	.10
5.57	.58	4.24	4.37	-.0777	-.0839	.0555	-.0319	.06
5.58	.29	3.68	3.83	-.0620	-.0638	.0453	-.0295	.03
5.59	-.01	2.75	2.94	-.0445	-.0391	.0263	-.0163	.01
5.60	-.10	1.66	1.86	-.0254	-.0150	.0069	-.0055	-.04
5.61	-.45	.36	.57	-.0050	.0099	-.0133	.0048	-.04
5.62	-.81	-1.10	-.91	.0162	.0346	-.0308	.0160	-.07
5.63	-1.18	-2.36	-2.18	.0377	.0577	-.0466	.0281	-.04
5.64	-1.35	-3.48	-3.35	.0590	.0747	-.0599	.0347	-.03
5.65	-1.46	-4.43	-4.31	.0695	.0918	-.0684	.0403	-.04
5.66	-1.39	-4.77	-4.66	.0788	.1034	-.0722	.0471	.04
5.67	-1.33	-4.88	-4.93	.0787	.1020	-.0681	.0444	.02
5.68	-1.16	-4.57	-4.65	.0722	.0912	-.0542	.0320	.04
5.69	-.99	-3.93	-4.00	.0555	.0736	-.0440	.0305	.05
5.70	-.61	-2.86	-2.98	.0325	.0479	-.0324	.0267	.05
5.71	-.46	-1.55	-1.63	.0089	.0215	-.0122	.0131	.05
5.72	-.15	-.40	-.47	-.0121	-.0055	.0132	-.0060	.06
5.73	.17	.98	.86	-.0321	-.0307	.0300	-.0148	.05
5.74	.38	2.21	2.10	-.0492	-.0520	.0450	-.0241	.05
5.75	.56	3.11	3.00	-.0640	-.0761	.0568	-.0315	.03
5.76	.67	3.97	3.88	-.0784	-.0944	.0648	-.0387	.04

TABLE II.- TIME HISTORIES OF TEST DATA - Continued

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
				M = 1.61				
4.57	-1.11	-4.27	-4.17	0.0694	0.0821	-0.0626	0.0426	-0.03
4.58	-1.15	-4.70	-4.61	.0750	.0895	-.0633	.0460	-.02
4.59	-.95	-4.72	-4.97	.0712	.0869	-.0580	.0421	-.02
4.60	-.81	-4.33	-4.40	.0631	.0774	-.0469	.0333	-.02
4.61	-.62	-3.46	-3.54	.0457	.0600	-.0368	.0296	-0
4.62	-.30	-2.40	-2.52	.0220	.0318	-.0138	.0108	-.02
4.63	-.03	-1.03	-1.12	.0013	.0072	-.0010	.0064	-.01
4.64	.31	.32	.22	-.0199	-.0149	.0164	.0005	-.01
4.65	.66	1.72	1.61	-.0390	-.0376	.0379	-.0168	-.02
4.66	.84	2.93	2.81	-.0559	-.0630	.0495	-.0215	-0
4.67	.86	3.82	3.73	-.0691	-.0799	.0587	-.0288	-.01
4.68	1.06	4.54	4.45	-.0784	-.0923	.0607	-.0315	.01
4.69	.96	4.73	4.79	-.0792	-.0945	.0569	-.0277	.01
4.70	.74	4.54	4.65	-.0746	-.0840	.0527	-.0293	.01
4.71	.51	4.06	4.17	-.0639	-.0707	.0384	-.0180	.02
4.72	.21	3.14	3.29	-.0473	-.0482	.0260	-.0139	.01
4.73	-.14	1.94	2.11	-.0280	-.0235	.0073	-.0005	.01
4.74	-.43	.64	.83	-.0076	.0014	-.0096	.0055	.01
4.75	-.70	-.65	-.50	.0182	.0263	-.0289	.0154	.01
4.76	-.97	-1.96	-1.80	.0384	.0483	-.0470	.0313	.02
4.77	-1.14	-3.18	-3.04	.0545	.0675	-.0579	.0362	.05
4.78	-1.28	-4.15	-4.04	.0678	.0828	-.0671	.0410	.06
4.79	-1.27	-4.67	-4.58	.0762	.0920	-.0704	.0465	.08
4.80	-1.19	-4.78	-4.83	.0751	.0932	-.0643	.0427	.10
4.81	-1.04	-4.51	-4.58	.0680	.0832	-.0557	.0394	.12
4.82	-.76	-3.77	-3.87	.0525	.0653	-.0409	.0287	.11
4.83	-.53	-2.71	-2.85	.0299	.0382	-.0262	.0214	.10
				M = 1.72				
3.81	2.11	2.48	2.38	-0.0453	-0.0461	0.0987	-0.0418	-0.31
3.82	2.08	3.53	3.47	-.0586	-.0630	.1021	-.0453	-.30
3.83	2.00	4.34	4.36	-.0703	-.0735	.0981	-.0493	-.32
3.84	1.68	4.68	4.68	-.0745	-.0783	.0855	-.0419	-.30
3.85	1.26	4.89	5.00	-.0688	-.0760	.0679	-.0335	-.26
3.86	.78	4.44	4.55	-.0625	-.0690	.0465	-.0279	-.21
3.87	.24	3.50	3.60	-.0483	-.0540	.0170	-.0111	-.10
3.88	-.47	2.41	2.54	-.0315	-.0343	-.0109	.0024	-.01
3.89	-1.00	1.20	1.33	-.0106	-.0100	-.0354	.0110	.12
3.90	-1.60	-.16	.01	.0065	.0146	-.0661	.0283	.21
3.91	-2.02	-1.56	-1.41	.0257	.0337	-.0851	.0352	.32
3.92	-2.25	-2.86	-2.66	.0432	.0591	-.1004	.0436	.42
3.93	-2.35	-3.96	-3.79	.0587	.0759	-.1089	.0530	.52
3.94	-2.29	-4.66	-4.50	.0673	.0878	-.1088	.0523	.59
3.95	-1.97	-4.87	-4.71	.0700	.0915	-.0999	.0451	.66
3.96	-1.73	-4.75	-4.74	.0641	.0830	-.0828	.0408	.63
3.97	-1.10	-4.20	-4.19	.0519	.0741	-.0548	.0263	.58
3.98	-.56	-3.27	-3.28	.0315	.0531	-.0295	.0130	.52
3.99	-.15	-1.93	-1.99	.0103	.0222	-.0022	.0030	.48
4.00	.40	-.51	-.54	-.0105	.0005	.0259	-.0036	.30
4.01	1.01	.82	.71	-.0262	-.0226	.0528	-.0173	.23
4.02	1.30	2.18	2.08	-.0443	-.0431	.0753	-.0308	.06
4.03	1.55	3.24	3.18	-.0599	-.0620	.0914	-.0441	-.03
4.04	1.81	4.33	4.30	-.0727	-.0757	.1013	-.0515	-.24
4.05	1.84	4.74	4.74	-.0788	-.0841	.0986	-.0450	-.33
4.06	1.72	4.80	4.92	-.0786	-.0828	.0924	-.0467	-.46
4.07	1.50	4.27	4.36	-.0688	-.0768	.0817	-.0390	-.52
4.08	.91	3.46	3.56	-.0559	-.0612	.0601	-.0273	-.54
4.09	.64	2.61	2.76	-.0377	-.0382	.0328	-.0154	-.52

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TABLE II.- TIME HISTORIES OF TEST DATA - Concluded

Time	α	δ_p	δ	$(C_h)_p$	C_h	C_N	C_m	β
$M = 1.77$								
3.50	0.39	-4.42	-4.35	0.0638	0.0700	0.0066	Not available	-0.08
3.51	.54	-4.61	-4.54	.0649	.0721	.0119		-.11
3.52	.66	-4.59	-4.67	.0611	.0705	.0160		-.12
3.53	.79	-4.32	-4.41	.0549	.0635	.0250		-.11
3.54	.92	-3.69	-3.76	.0452	.0558	.0353		-.12
3.55	1.00	-2.87	-2.97	.0301	.0400	.0385		-.10
3.56	1.16	-1.72	-1.78	.0126	.0233	.0411		-.10
3.57	1.20	-.55	-.58	-.0032	.0060	.0468		-.04
3.58	1.17	.63	.54	-.0192	-.0132	.0457		-.01
3.59	1.13	1.84	1.74	-.0339	-.0317	.0448		.04
3.60	.94	2.92	2.84	-.0469	-.0493	.0449		.07
3.61	.58	3.80	3.78	-.0588	-.0592	.0332		.06
3.62	.28	4.35	4.34	-.0675	-.0671	.0193		.07
3.63	-.12	4.44	4.41	-.0691	-.0716	.0103		.09
3.64	-.40	4.42	4.54	-.0619	-.0674	-.0074		.13
3.65	-.87	3.79	3.91	-.0530	-.0561	-.0260		.19
3.66	-1.28	3.10	3.27	-.0409	-.0393	-.0439		.23
3.67	-1.52	1.99	2.16	-.0241	-.0209	-.0577		.25
3.68	-1.83	.80	.96	-.0038	-.0004	-.0705		.30
3.69	-1.95	-.56	-.40	.0119	.0187	-.0802		.31
3.70	-1.91	-1.95	-1.79	.0303	.0385	-.0832		.37
3.71	-1.88	-3.15	-2.99	.0461	.0568	-.0829	-0.0280	.37
3.72	-1.63	-4.07	-3.94	.0597	.0718	-.0708	-.0099	.31
3.73	-1.23	-4.63	-4.55	.0672	.0787	-.0585	.0128	.25
3.74	-.77	-4.80	-4.84	.0681	.0812	-.0385	.0204	.19
3.75	-.31	-4.66	-4.68	.0578	.0749	-.0178	.0169	.15
3.76	.16	-3.99	-4.01	.0439	.0614	.0078	.0056	.07
3.77	.76	-2.99	-3.05	.0265	.0420	.0333	-.0046	-.05
3.78	1.19	-1.75	-1.79	.0058	.0193	.0557	-.0180	-.10
3.79	1.67	-.36	-.36	-.0153	-.0018	.0731	-.0259	-.17

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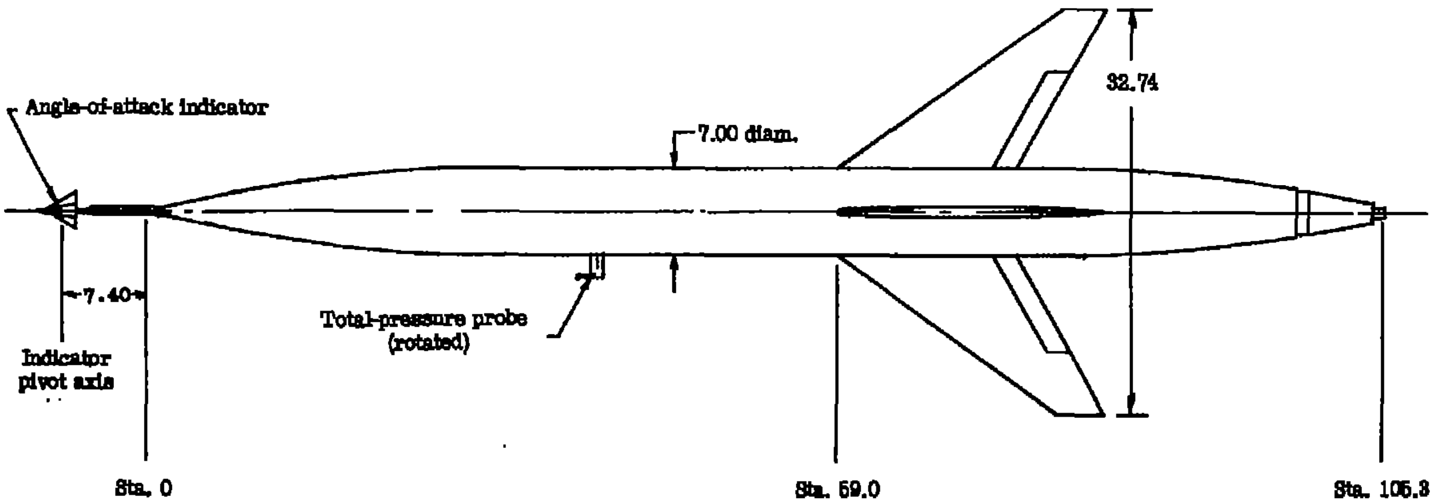
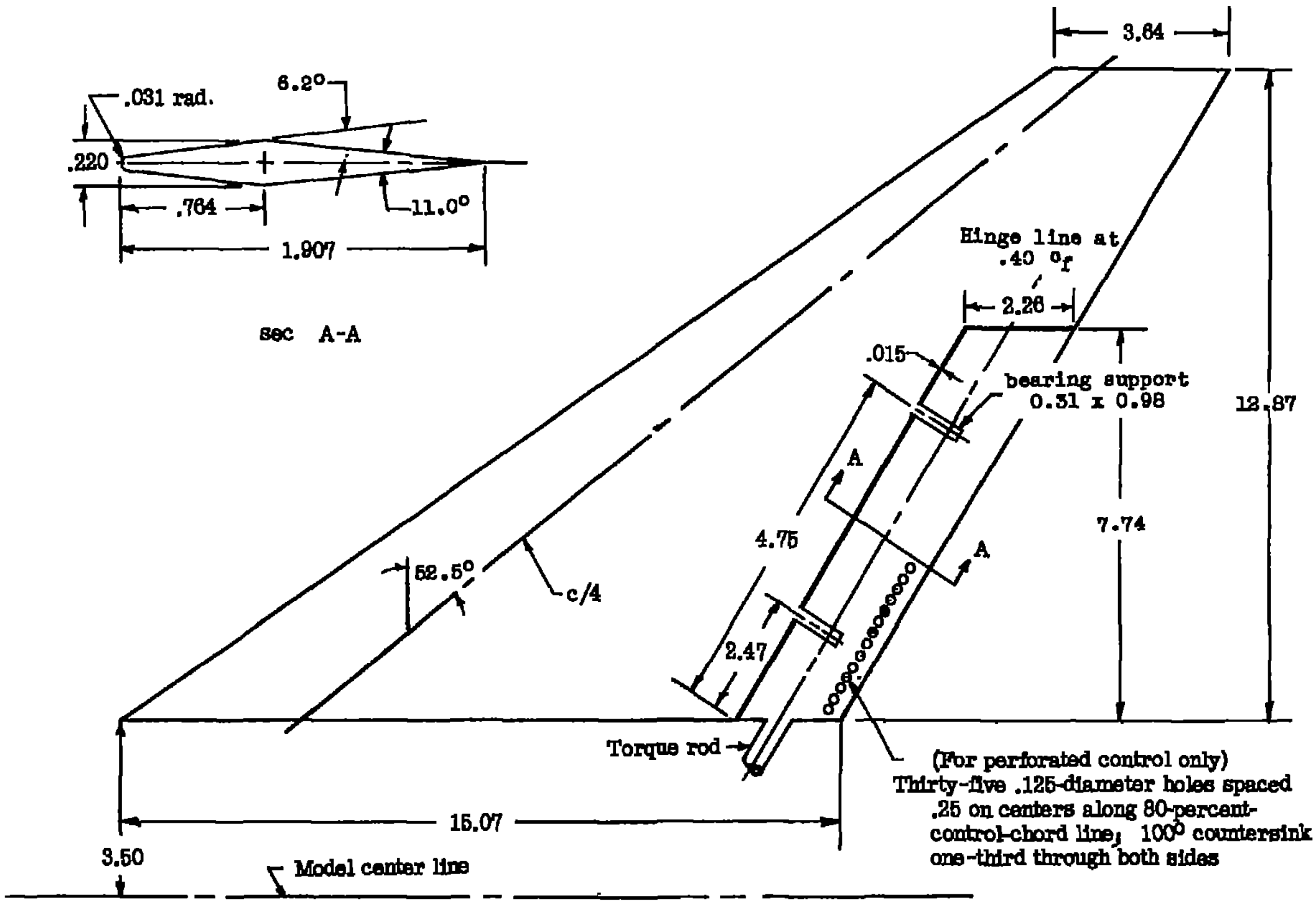


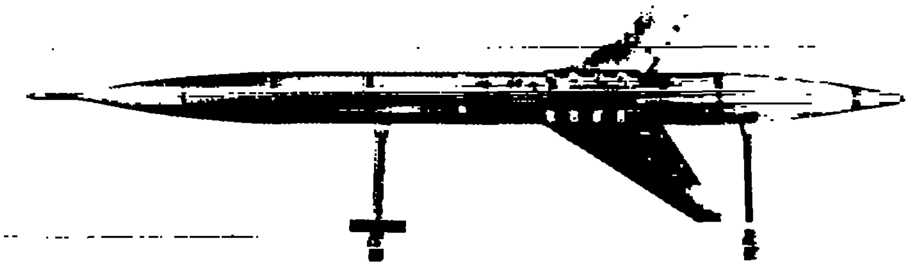
(a) Plan view of test vehicle.

Figure 1.- Model design. All dimensions are in inches unless otherwise indicated.

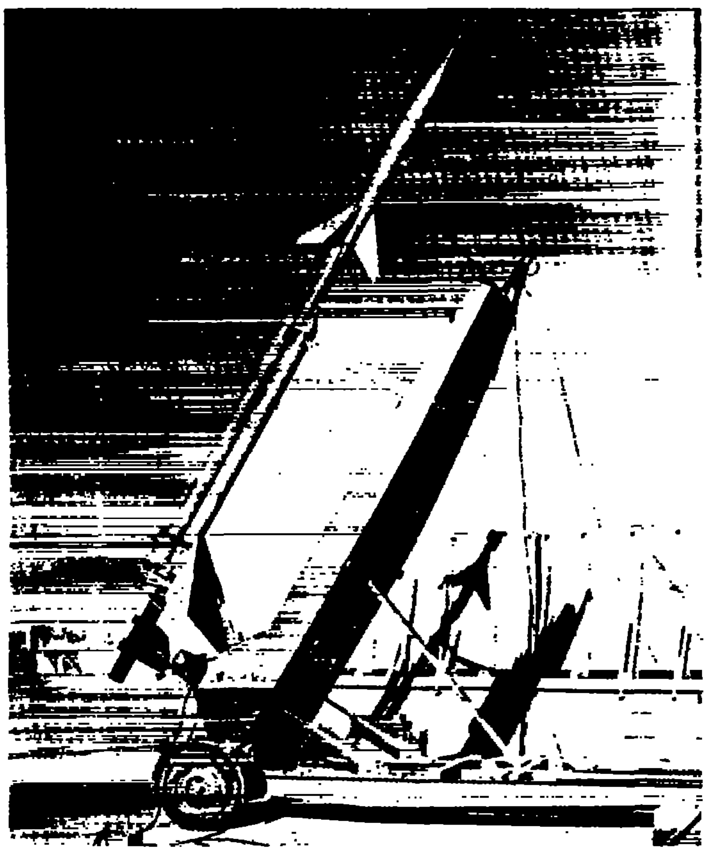


(b) Control wing.

Figure 1.- Concluded.



(a) Plan view.



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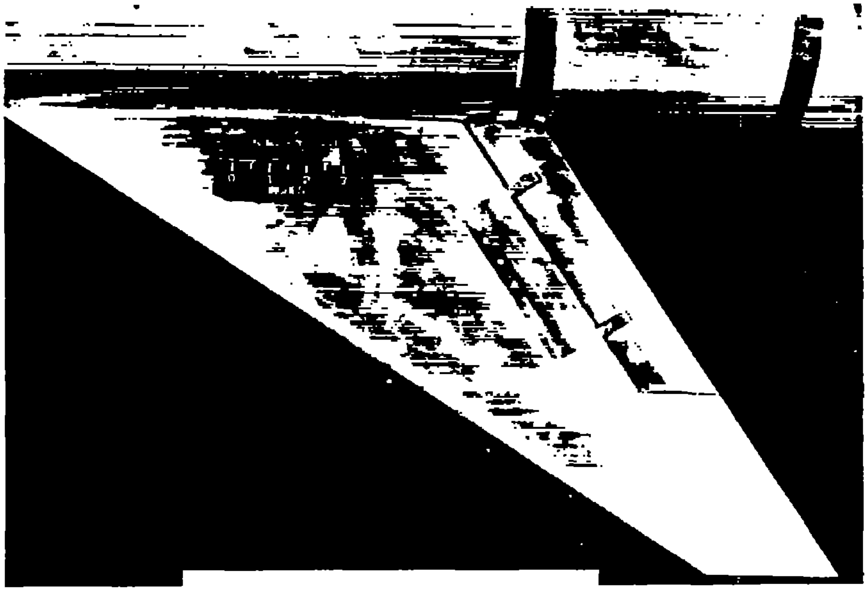
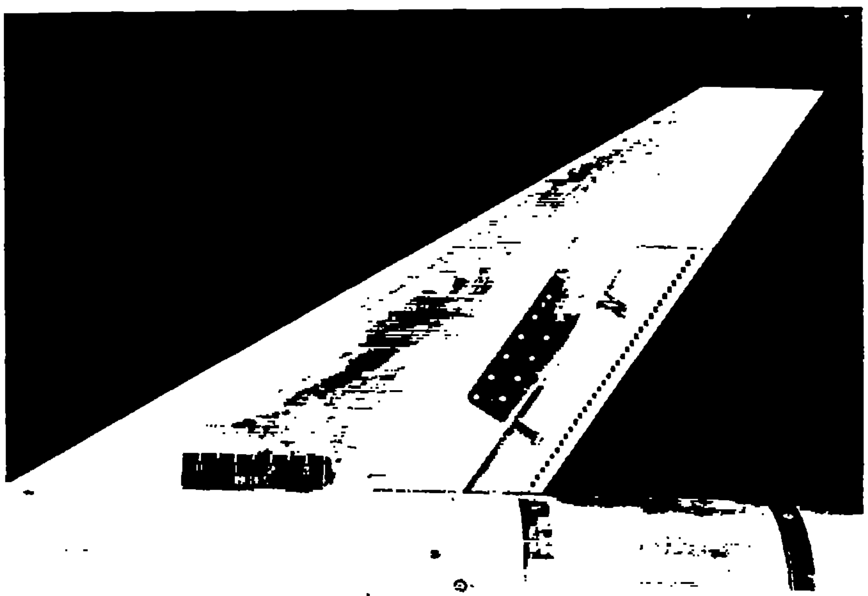
(b) Model and booster preparatory to launching.

Figure 2.- Test vehicle.



L-86331

(c) Wing with solid control.



L-86330

(d) Wing with perforated control.

Figure 2.- Concluded.

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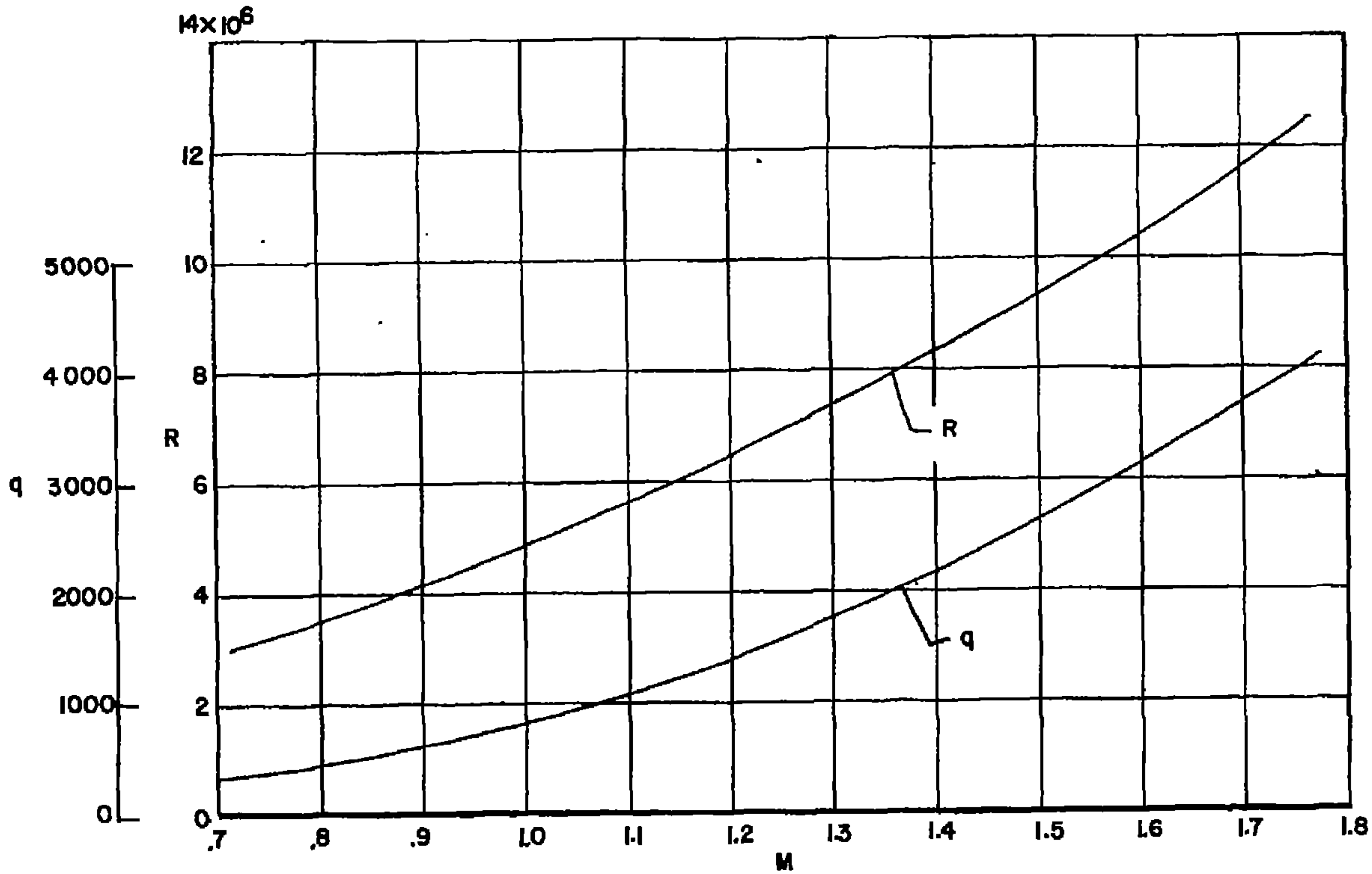

Figure 3.- Variation of Reynolds number and dynamic pressure with Mach number.

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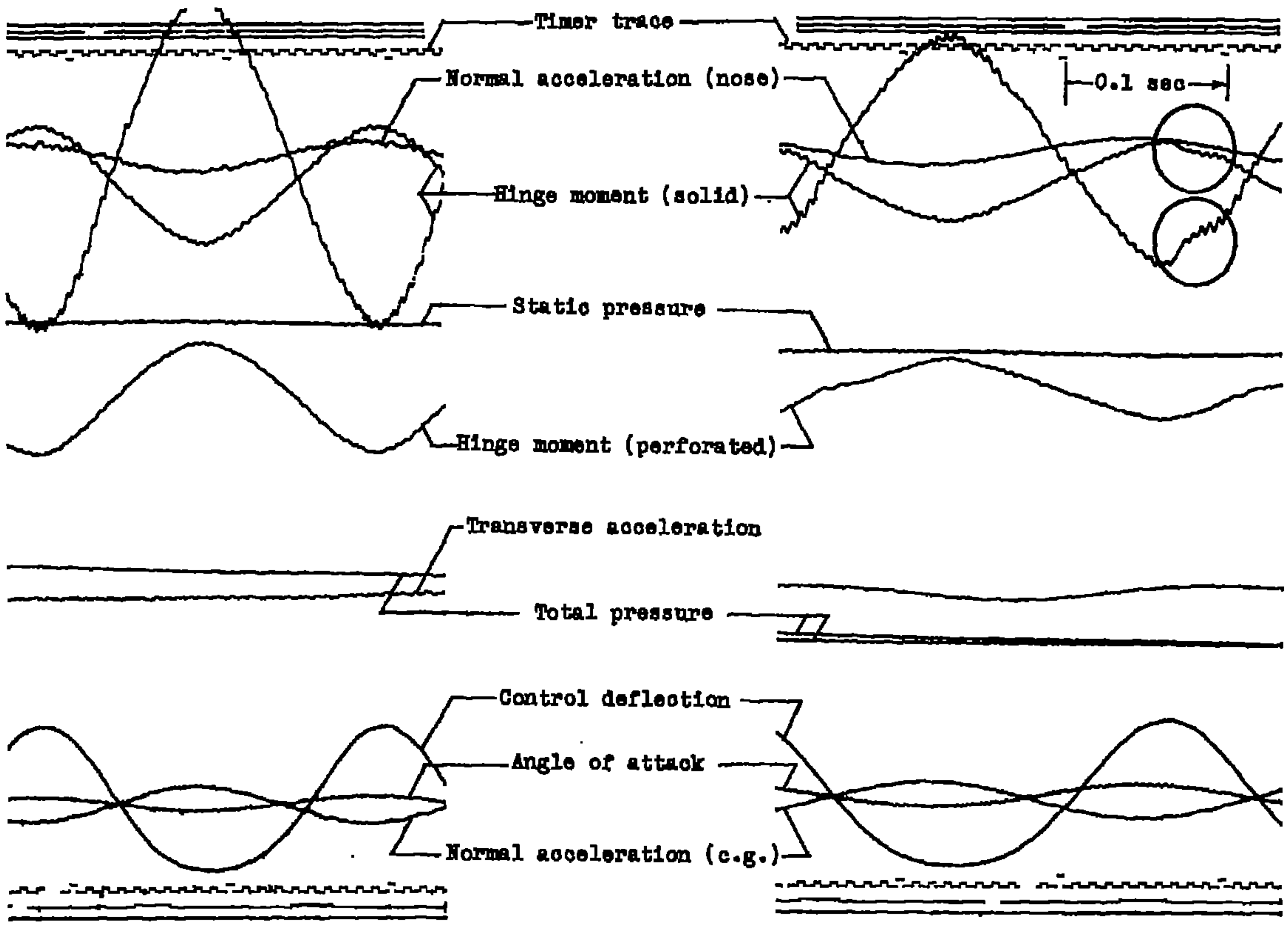
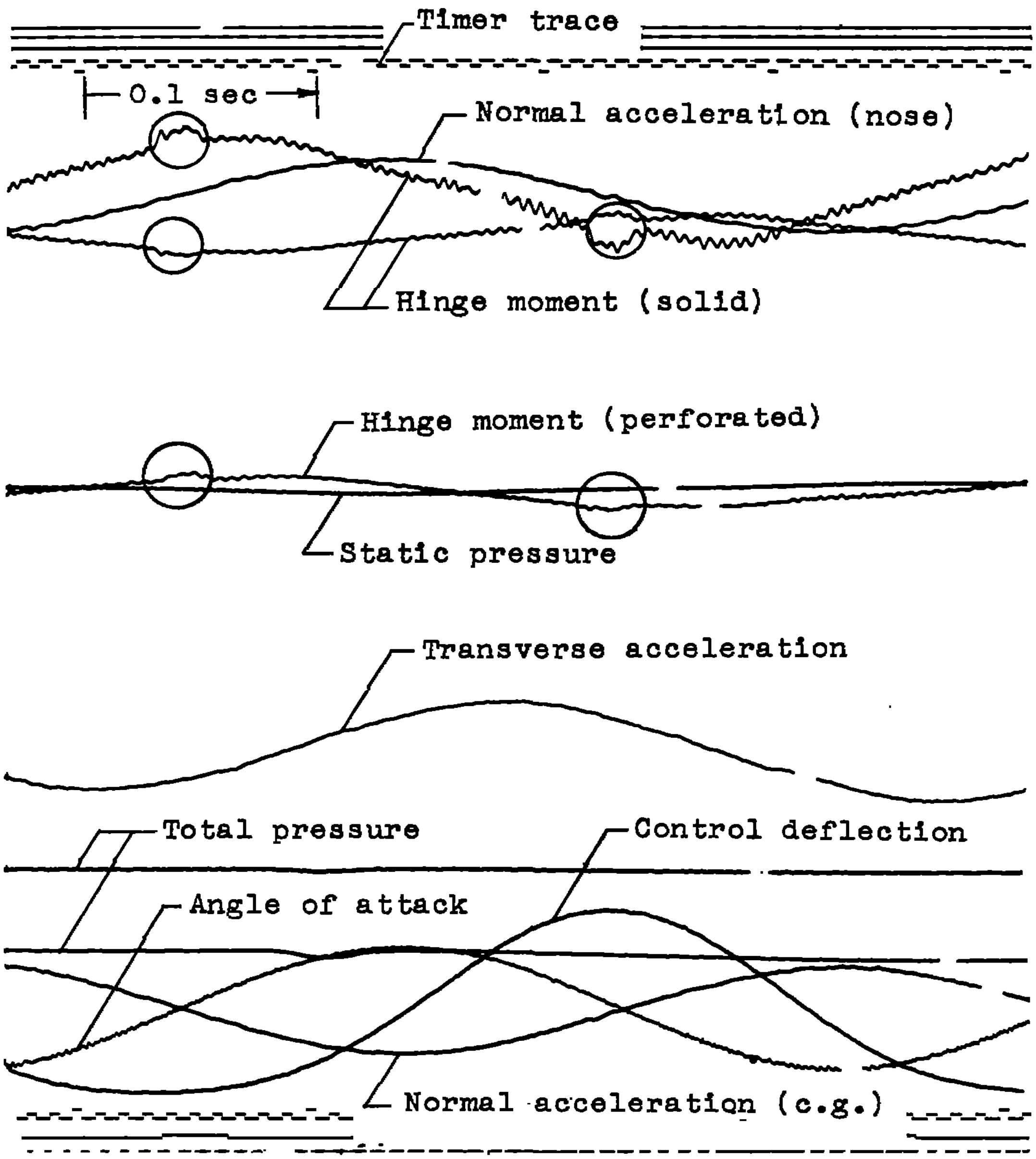


(a) M = 1.61.

(b) M = 1.30.

Figure 4.- Sample sections of telemeter record. Hinge-moment "irregularities" indicated by circles.

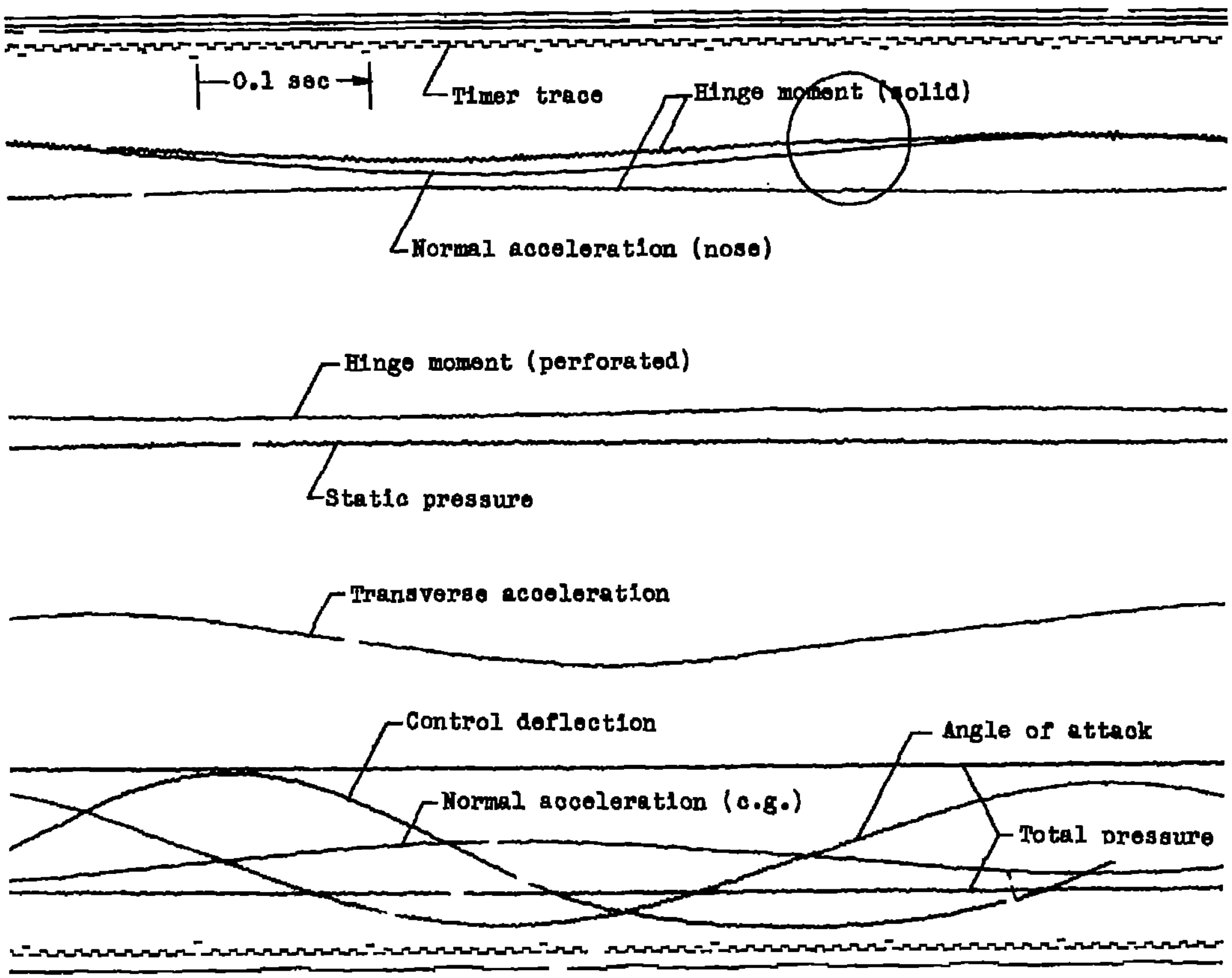
[redacted]



(c) M = 1.02.

Figure 4.- Continued.

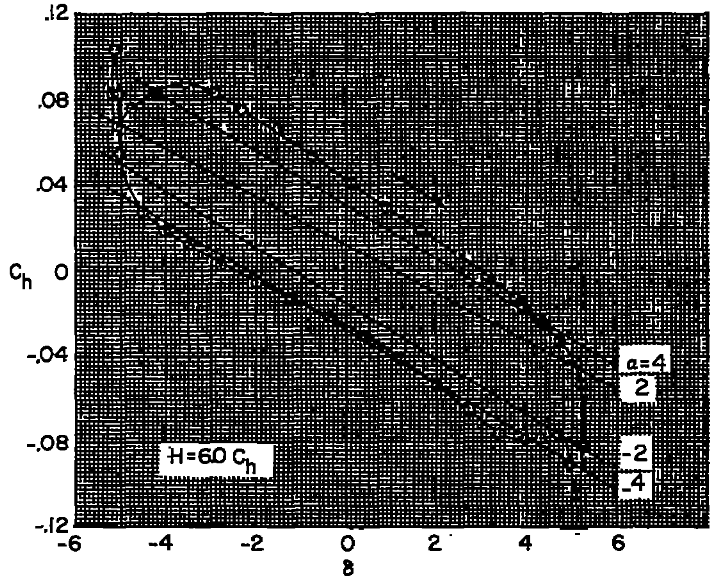
[redacted]



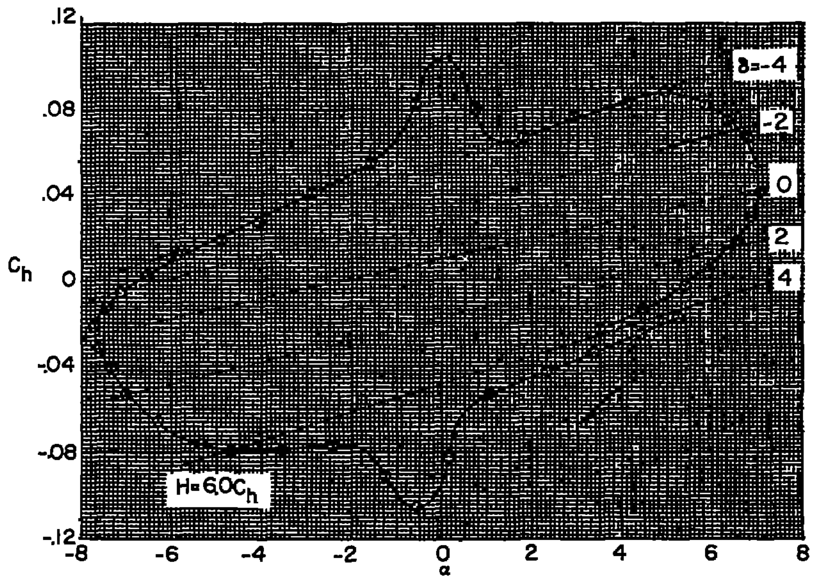
(d) M = 0.71.

Figure 4.- Concluded.

[redacted]



(a) Variation of C_h with δ.



(b) Variation of C_h with α.

Figure 5.- Sample variation of C_h with α and δ for the solid control at M = 1.02. Arrows indicate time sequence of recorded data.

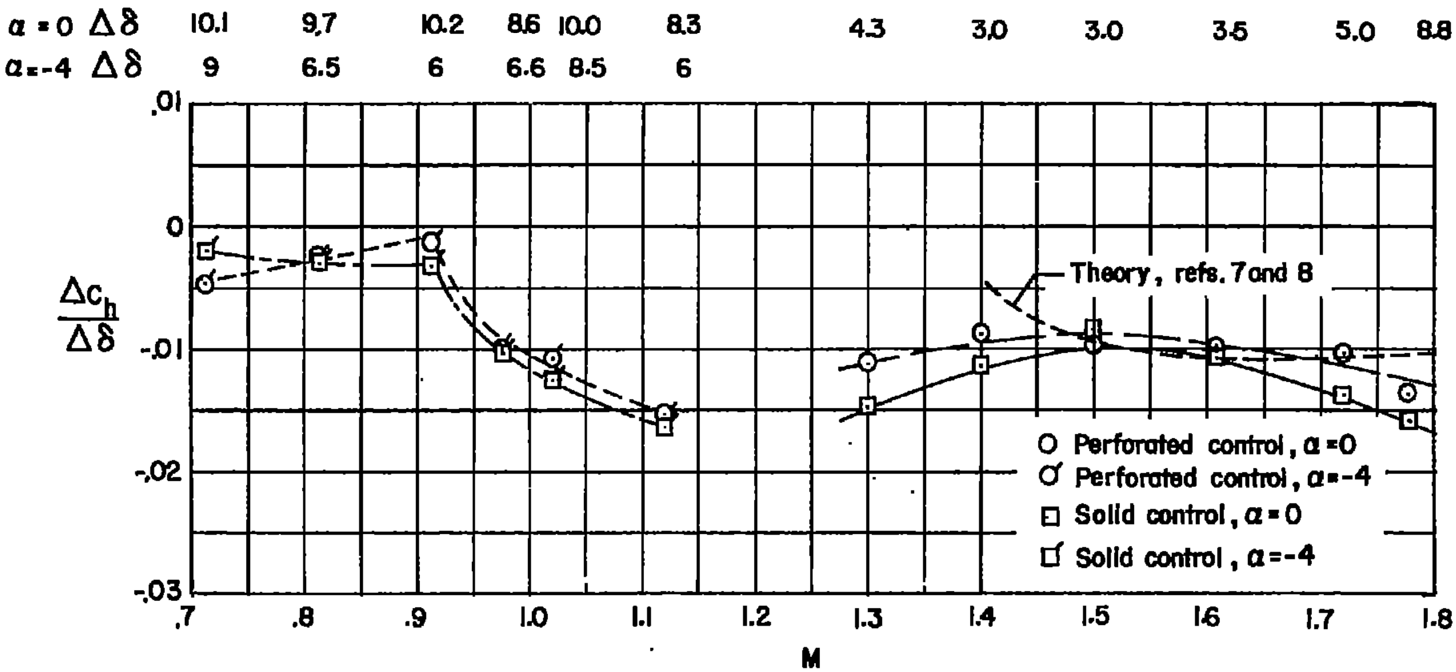


Figure 6.- Variation with Mach number of the change in control hinge-moment coefficient with respect to control deflection. Δδ indicated.

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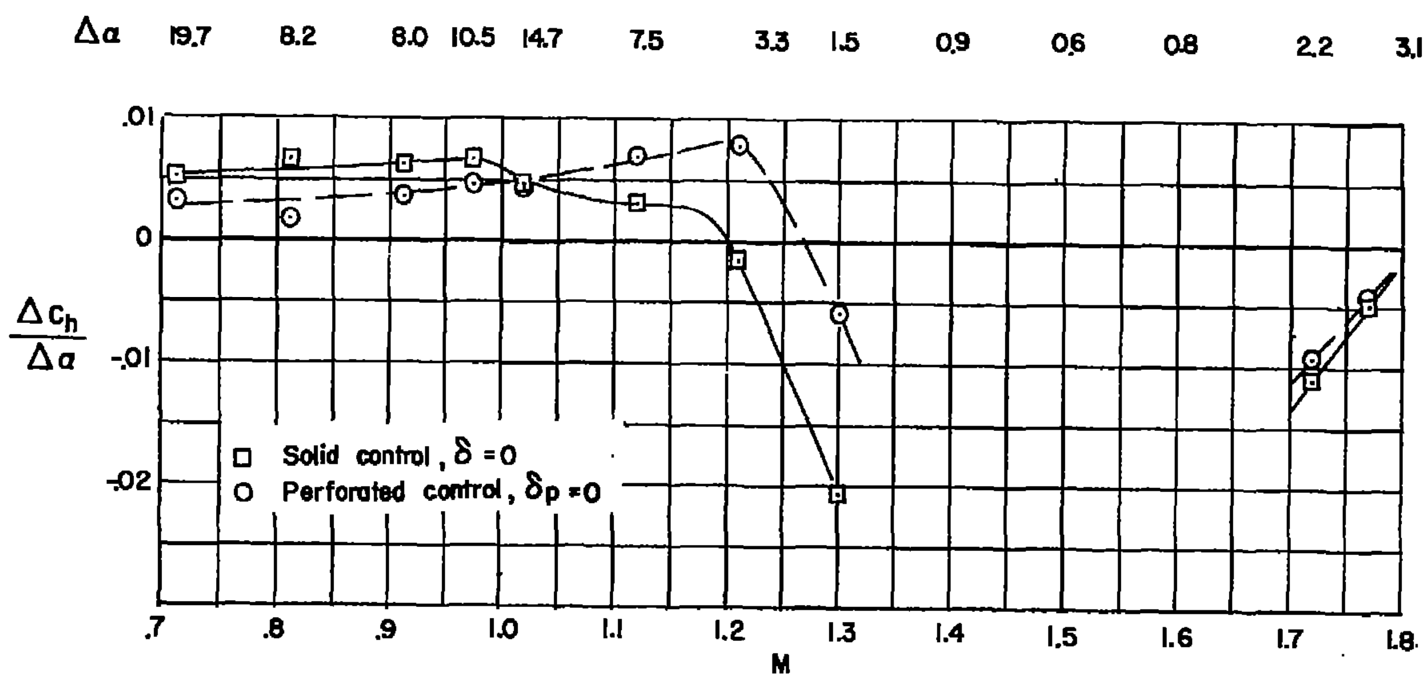

Figure 7.- Variation with Mach number of the change in control hinge-moment coefficient with respect to angle of attack. $\Delta\alpha$ indicated.

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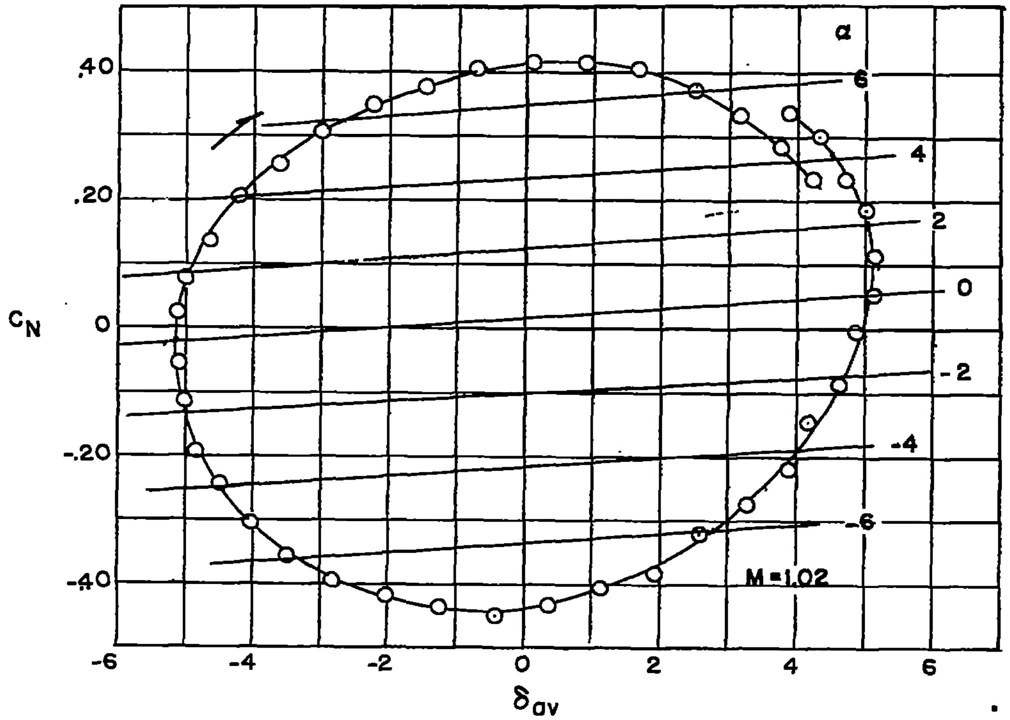

Figure 8.- Variation of model normal-force coefficient with control deflection showing lines of constant angle of attack at M = 1.02. Arrow indicates time sequence of recorded data.

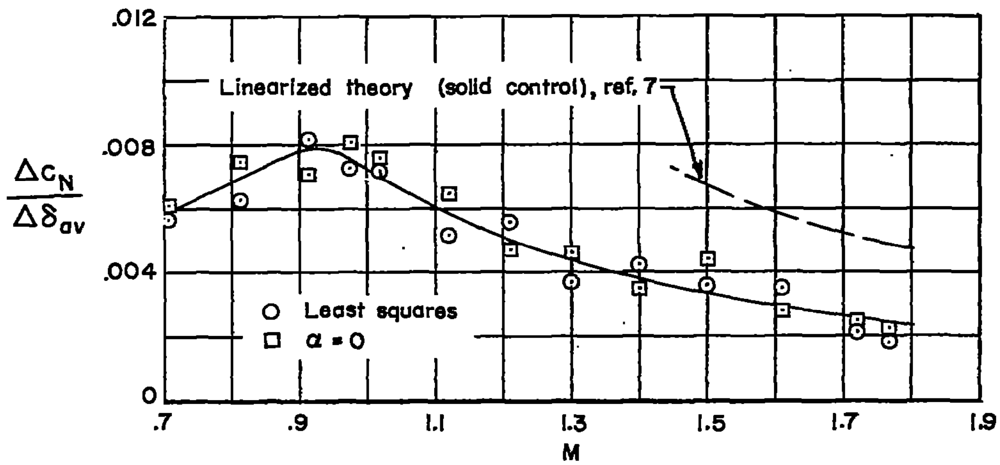

Figure 9.- Variation with Mach number of the change in model normal-force coefficient with respect to control deflection.

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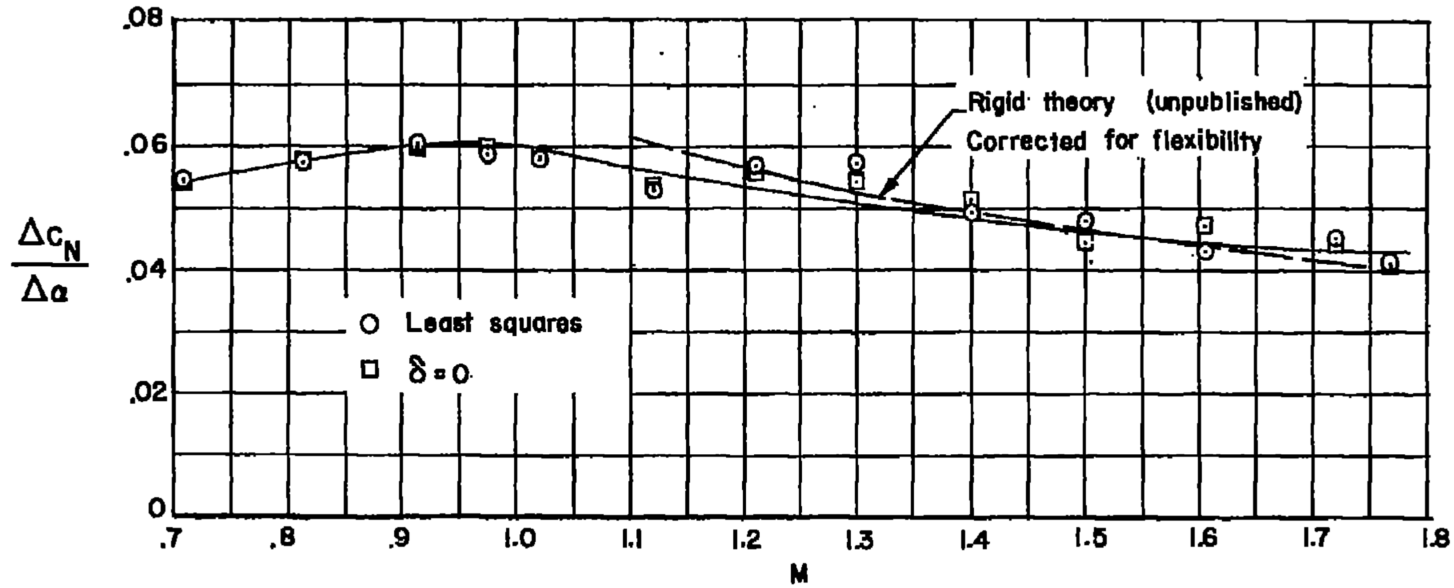

Figure 10.- Variation with Mach number of change in model normal-force coefficient with respect to angle of attack.

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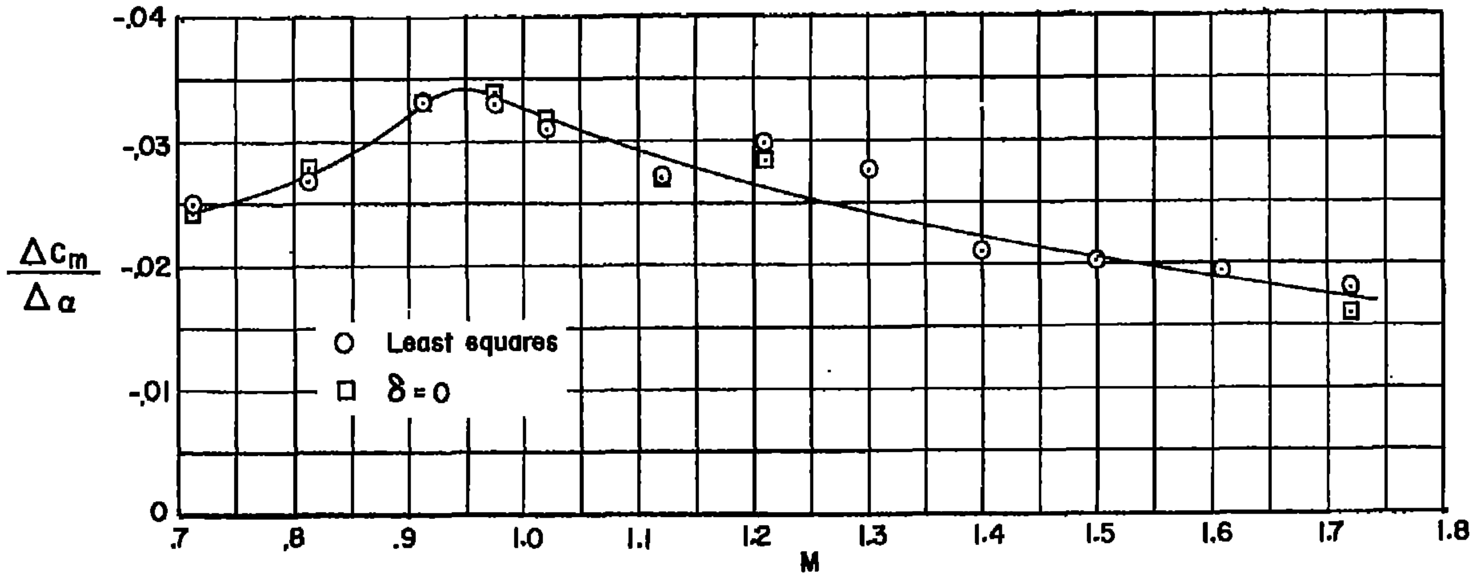

Figure 11.- Effect of Mach number on model pitching-moment derivative.

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